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EXPERIMENTS ON THE MANURING OF FRUIT TREES.—II.*

By T. WALLACE, M.C., M.Sc., A.I.C.

University of Bristol Agricultural and Horticultural Research Station, Long Ashton, Bristol.

Experiments with Gooseberry Bushes.

The variety used was "King of Trumps." The bushes, thirteen per series, were planted on March 9th, 1922. Previous to planting the roots were severely pruned and after planting the shoots were pruned back close to the main stems.

The treatments given and the procedure followed in this experiment were similar to those in the experiment with apple trees.

In addition, the following special treatments were given to some of the bushes.

(*a*) Two bushes per series did not receive the fortnightly leaching treatment with water.

(*b*) Two bushes per series were lifted at the end of each season for root examination after which they were root pruned and replanted in their respective pots.

Data referring to the following points were collected :—

(*a*) Times of opening of leaf and blossoms.
(*b*) Blossom characters.
(*c*) Foliage characters throughout the season.
(*d*) Shoot growth.
(*e*) Defoliation.
(*f*) Crop weights and characters of fruits.
(*g*) Root systems.
(*h*) Effects of non-leaching treatment.

As the observations made on certain of the above phenomena were of the same nature as those made in the experiments on apple trees, the observations recorded in such cases will not always be discussed in detail in the following account of these.

(*a*) *Times of opening of leaf and blossom.*

The observations on these were similar in character to those recorded in the experiment on apple trees, the plants in the Series C., E., H. starting into growth very weakly and lagging behind the plants in the other series, in which bud break was very similar.

* Part I. appeared in Nos. 3 and 4, Vol. 4, of this Journal.

Thus on April 3rd, 1923, the number of plants with open blossoms were as under :—

Series A—nine plants ; Series C—five plants ; Series D—nine plants ; Series E—two plants ; Series F—ten plants ; Series G—ten plants ; Series H—four plants.

On that date the condition of the foliage was as follows :—

Series A.—Foliage almost fully developed.
,, C.—Buds just breaking into growth.
,, D.—Condition as in Series A.
,, E.— ,, ,, ,, C.
,, F.— ,, ,, ,, A.
,, G.— ,, ,, ,, A.
,, H.— ,, ,, ,, C.

(*b*) *Blossom Characters.*

The blossoms in Series C, E, H were weakly developed in seasons 1923, 1924. A count of the actual blossoms on the bushes, exclusive of the root pruned bushes, was made on April 23rd, 1923. The data for this are recorded in Table V.

TABLE V.

Blossom Count on Gooseberry Bushes.

Series ..	A.	C.	D.	E.	F.	G.	H.
Total number of blossoms.	663	302	708	795	680	831	336

It will be noted in the table that the numbers of blossoms in Series C, H were much smaller than those in the other series. A point requiring explanation is the high number recorded in Series E. The blossoms formed in 1923 were determined by the growth conditions obtaining in 1922, the first season of the experiment. During that season the bushes in the series made good shoot growth as the effects of phosphorus starvation did not come into full operation until 1923 when shoot growth was very much restricted and lateral buds became greatly weakened. During 1924, there was scarcely any blossom in the series as practically all lateral buds failed to break. Unfortunately blossom data were not obtained during the latter season owing to bird damage. (See also data for size of fruits in 1923.—Table VII.)

(*c*) *Foliage characters.*

Series A.—The bushes in this series were well furnished with healthy green foliage during each growing season and the leaves were normal in every respect.

Series C.—As early as June, 1922, the foliage in this series began to show symptoms of malnutrition. The leaves were smaller than in Series A, were pale green in colour and eventually developed strong yellow and red tints. In 1923, the amount of foliage carried by the bushes was relatively small, the leaves also being small in size throughout the season, whilst as early as May 13th they showed much tinting. These conditions were even more marked during 1924.

Series D.—The foliage during the greater part of 1922 was similar to that in Series A. and it was not until the autumn that characteristic symptoms were developed. At that time all the bushes showed a certain amount of marginal leaf scorch which became very marked just previous to defoliation. In 1923, characteristic symptoms were in evidence from an early date. By May 20th, much of the foliage had developed purplish-red tints whilst the green of the leaves was much duller than in Series A. The development of the tints was closely followed by scorching of the leaves, this condition being first recorded on May 27th. By June 17th practically every leaf in the series showed marginal scorch.

In 1924, the tinting and scorching were developed still earlier than in 1923, scorch being very severe on all bushes by May 24th. From that date until defoliation, the leaves were in very poor condition, showing marked tinting, severe leaf scorch and much curling of the edges towards their under surfaces.

Series E.—As in the experiments with apple trees very characteristic symptoms were developed on the leaves in this series, and these symptoms were very similar to those shown by those trees. During the first season of the experiment the foliage was fairly normal until August when marked purpling was developed. This purpling gradually faded into a characteristic bronzing. In the second season of the experiment the purpling and bronzing were in evidence by May 13th, before which date the leaves had been a dull green colour, and by June 8th there was practically no green colour remaining on any of the leaves.

Similar observations were recorded in 1924. The amount of foliage in this series was very small after the first season, the leaves being small in size and few in number. As with the apple trees the foliage carried became practically confined to the tips of the shoots during the last two seasons owing to the buds along the shoots failing to break.

Series F.—The foliage in this series did not differ to any great extent either in amount or character from that in Series A. On certain occasions, however, during each season, the green of the leaves was rather pale and bands of red colour were developed around the leaf margins.

Similar bands were developed on the leaves in Series G, but in that series they were developed to a very marked degree, practically every leaf in the series showing this feature. During the autumn the tints in Series F. were generally predominantly purple whereas in Series A. they were orange and red.

Series G.—The amount of foliage borne by the bushes in this series was similar to that in Series A. but differed very markedly in appearance from it. During the very early days of each season the leaves developed in normal fashion but soon showed very characteristic features. Broad red bands developed around the margins of the leaves and these gradually widened inwards towards the centres of the leaves until, finally, practically the whole of the green disappeared from the leaves. This red colouration usually became less intense after a while and gradually faded into a faint yellow. The leaves were generally shed when this latter point was reached.

It is of interest to note that similar tints are strongly developed in the autumn by the variety "Whinham's Industry."

These characteristic tints are no doubt due to some breakdown in chlorophyll synthesis.

The condition was strongly marked by mid July in 1922, by June 17th in 1923, and by June 14th in 1924, and appeared to develop very quickly under conditions of bright sunshine.

Series H.—The condition of the foliage in this series was very similar to that in Series C, the only difference being that, as in the case of apples, the red tints developed were more intense than in the latter series.

(*d*) *Shoot Growth.*

The data relating to shoot growth for the first two seasons of the experiment are presented in Table VI.

The salient points brought out in these are :—

1. The amount of shoot growth was similar in Series A, F, G.
2. The amount was somewhat smaller than in these series in Series D.
3. Growth was very much reduced by the treatments in Series C, E, H.
4. The growth in Series E was not much restricted during the first season of the experiment but fell off very much in the second season.

TABLE VI.

Shoot Growth of Gooseberry Bushes—Leached Series.

Season 1922.

Series.	No. of bushes.	Total shoot growth. mms.	Average shoot growth per bush. mms.	Length of longest shoot. mms.
A.	10	16345	1634.5	270
C.	10	6275	627.5	120
D.	10	10210	1021.0	205
E.	10	12570	1257.0	230
F.	10	10125	1012.5	220
G.	10	13005	1300.5	285
H.	10	6030	603.0	150

Season 1923.

Series.	No. of bushes.	Total shoot growth. mms.	Average shoot growth per bush. mms.	Length of longest shoot. mms.
A.	8	19140	2392.5	300
C.	8	1650	206.3	80
D.	8	12950	1618.8	355
E.	8	4205	525.6	110
F.	8	25300	3162.5	285
G.	8	27370	3421.3	305
H.	8	1990	248.8	105

In this connection it may be stated that during 1924 practically no shoot growth was made by any of the bushes in this series.

Comparison of these results with those obtained for apple trees will show that they are very similar in character in the two experiments.

(*e*) *Defoliation.*

In this experiment defoliation was hastened by early cessation of growth in the three Series C, E, H, and was brought about prematurely by external conditions in the Series D, G. Thus it will be seen that these results are similar to those obtained with apple trees. The effects of the treatment in Series G, in causing early defoliation were not so severe on gooseberry bushes as on apple trees, as will be seen by examination of data given below on the course of defoliation of the bushes during the experiment. The effects of treatment E, on gooseberries were very great.

In 1922 the various treatments did not produce very striking effects on time of defoliation except perhaps in Series E, C, H. In that season defoliation

in these latter series commenced about mid-August in Series E, and about mid-September in Series C, H, whilst there was practically no defoliation in the other Series by October 31st, after which date defoliation proceeded at a very rapid rate.

The following notes show the progress of defoliation from that date.

Order of Retention of Foliage, 1922.

Oct. 31st.—Series A, D, F, G.—Retained practically all their foliage.
Series E.—Practically defoliated.
Series C, H.—Defoliated.

Nov. 7th.—Series A, D, F, G.—Only retained tip foliage.
Series C, E, H.—Defoliated.

Nov. 23rd.—Series A, D, F, G.—Practically defoliated.
Series C, E, H.—Defoliated.

In 1923, the effects of the treatments on defoliation in Series E were very marked. Defoliation began as early as June 24th and by July 18th, 50 per cent. of the foliage had fallen. Defoliation commenced in Series C, H, during the first week of September. In Series G, there was some defoliation during a spell of hot weather around July 18th, but after this no further defoliation occurred until September 24th. Defoliation was first noted in any quantity in the remaining series about mid-October.

Order of Retention of Foliage, 1923.

Sept. 8th.—Series A, D, F, G,—Defoliation practically nil.
Series C, H.—Defoliation 20 per cent. approximately.
Series E.—Only retained tip foliage.

Sept. 24th.—Series A, F, D.—Defoliation practically nil.
Series G.—A little defoliation.
Series C, H.—Only retained tip foliage.
Series E.—Practically defoliated.

Oct. 14th.— Series E.—Defoliated.

Oct. 22nd.—Series A, F.—Approximately 20 per cent. defoliated.
Series D, G.—Approximately 50 per cent. defoliated.
Series C, E, H.—Defoliated.

Nov. 1st.— Series A, F.—40 per cent. defoliated.
Series G.—60 per cent. defoliated.
Series D.—80 per cent. defoliated.

Nov. 23rd.—All series defoliated.

During 1924, defoliation took place earlier than in 1923 in all series, which was probably due to seasonal influences. Apart from this, further marked effects were produced on defoliation in Series D, E, over those in 1923.

Thus in Series E, defoliation commenced as early as May 28th during a few days of hot weather whilst in Series D, there was much defoliation following leaf scorch as early as August 9th. The percentage of defoliation in this latter series was greater than in Series C, H, until the beginning of September, from which date defoliation progressed rapidly in these series.

Order of Retention of Foliage, 1924.

Series E.—May 28th, much defoliation ; June 14th, 40 per cent. defoliated ; June 27th, 80 per cent. defoliated ; July 16th, only tip foliage retained.

Aug. 9th.— Defoliation commenced in Series D.

Sept. 7th.—Series A, F, G.—Slight defoliation.
Series D.—Approximately 40 per cent. defoliated.
Series C, H.—Approximately 50 per cent. defoliated.
Series E.—Practically defoliated.

Sept. 19th.—Series A, F, G.—Slight defoliation.
Series D.—40 to 50 per cent. defoliated.
Series C, E, H.—Practically defoliated.

Oct. 5th.—Series A, F, G.—Defoliation 10 to 20 per cent.
Series D.—Defoliation 70 per cent.
Series C, E, H.—Defoliated.

Oct. 31st.—Series A, F, G.—Defoliation 90 per cent.
Series D.—Defoliated.

During the period of defoliation the tints developed were as follows :—

Series A.—Mostly orange and red.
Series C.—Intense yellow and red.
Series D.—Purplish reds and brown marginal leaf scorch.
Series E.—Purple and bronze.
Series F.—Purple and reds with some red bands as in Series G.
Series G.—Wide red marginal bands which faded to a pale whitish-yellow.
Series H.—Red as in C, though generally more intense.

(*f*) *Crop Weights and Characters of Fruits.*

Crop weights were taken for the 1923 crop. The data relating to these are presented in Table VII.

TABLE VII.

Cropping of Gooseberry Bushes, 1923.

Series.	No. of bushes.	Total number of fruits.	Total Weight of fruits. grms.	Average Weight per fruit. grms.
A.	10	256	565.9	2.18
C.	10	65	74.2	1.14
D.	10	329	774.1	2.35
E.	10	390	533.8	1.37
F.	10	181	489.9	2.70
G.	10	298	887.7	2.98
H.	10	125	147.2	1.18

It was proposed also to record the crop weights for 1924 but unfortunately it was not possible to do so owing to the buds on the bushes being attacked by birds during the spring of that year.

As 1923 was the first season that a crop was taken from the bushes, the order of cropping shown in the table does not necessarily indicate which treatments will ultimately affect the cropping powers of the plants to the greatest extent. In this connection attention has already been drawn to the effects produced on bud formation in Series E, during season 1924.

It is of interest to note that even at the early stage in the experiment at which these data were obtained, the weights of the fruits in Series C, E, H, were reduced considerably below the weights of those in the other Series.

Examinations of the fruit characters were made at intervals during 1924 and it was noted that the quality of the fruits in Series E stood out very distinctly from those in the other series. They were extremely acid to taste and lacked flavour whilst the fruits in the other series showed no marked differences. The fruits in series E also showed to a small extent the dull green and bronzed colours characteristic of the leaves in the series and there were purple spots dotted over their surfaces.

(*g*) *Root systems.*

Two plants per series were removed from the pots for root examination on November 23rd, 1922, and one per series on January 21st, 1924. Photographs of the latter are shown in Plate I, Fig. b. The main observations recorded on these dates are as follows :—

November 23rd, 1922.

Size of Roots.

Series A, D, G.—The roots were very similar, being slightly smaller in Series D.

Fig. A.

Fig. B.

PLATE I.

Figs. A and B show the comparative shoot and root development of Gooseberry bushes resulting from the different nutrient treatments.—July 31st, 1924.

Series E, F.—The root systems were much smaller than in Series A, etc.

Series C, H.—These roots were much smaller than those in Series E, etc.

Characters of Roots.

Series A, G.—The roots in both series showed excellent development of both coarse and fine fibre.

Series D.—The roots were similar to those in Series A, but the amount of fine fibre was less.

Series E, F.—The roots lacked fine fibre.

Series C, H.—The roots consisted almost entirely of fine fibrous material.

January 21st, 1924.

Series A, F, G.—The root systems in these series were large and the coarse and fine fibre were normal in character. The root of the plant from Series G showed much blackened fibre.

Series D.—This root system was smaller than those in Series A, etc., and fine fibre was not so well developed.

Series C, H.—These roots were much behind that in Series D in size. They consisted almost wholly of fine fibrous growths.

Series E.—This root was the smallest of all the roots and consisted of poorly developed coarse fibre, fine fibre being practically absent. The colour of the root was brown as though indicating lack of recent activity.

(*h*) *Effects of non-leaching.*

In this experiment this treatment resulted in larger growth than in the leached series and appeared to prolong the growth period each season. The tints developed during the autumn were not generally as bright as those receiving the same nutrient solutions plus leaching and there was a tendency for the plants to exhibit leaf scorch symptoms instead of developing the characteristic tints of the various series.

SUMMARY OF RESULTS ON GOOSEBERRY BUSHES.

1. The times of opening of leaf and blossom buds were delayed by the treatments given in Series C, E, H.
2. Blossom development became much restricted in Series C, E, H, after the second season.
3. Very definite foliage characters were produced by each of the treatments. The relative amounts of foliage in the series were similar to those in the experiment on apple trees. The tints, etc., developed in the respective series in the experiment in Series A, C, D, E, H, were similar to

those developed in these series in the experiment on apple trees though showing minor points of difference. Thus, with gooseberries in Series D, leaf scorch was accompanied by reddish-purple tints and in Series C, H, the red tints developed were much more intense than those developed on apple trees.

In series F purple tints were developed and, to a slight extent, marginal red bands appeared as in Series G. In Series G, a very characteristic marking of the leaves was strongly developed in each season.

4. Shoot growth was greatly restricted in the first season in Series C, H, and in the second season in Series E. It was also restricted to a certain extent in Series D.
5. Defoliation was greatly hastened by treatments E, C, H, and to a less extent by treatment D. The effect of treatment G on defoliation was not so marked as with apple trees.
6. The size of the fruits in Series C, E, H, was much smaller than in the other series in the second season of the experiment. In this season the crops were very small in Series C, H. The quality of the fruits was notably affected in Series E.
7. Root growth after two seasons was very small in Series C, E, H, and corresponded with the lack of shoot growth in these series.

Experiment with Black Currant Bushes.

The variety used in this experiment was Seabrook's Black. The bushes were planted in the pots on March 14th, 1922. Previous to planting most of the root system of each of the plants was removed and the shoots were cut right down after planting. There were thirteen bushes in each series and the treatments and procedure were as in the experiment with gooseberry bushes.

During the experiment data were obtained for the following :—

(*a*) Times of opening of leaf and blossom buds.
(*b*) Blossom characters.
(*c*) Foliage characters throughout the season.
(*d*) Shoot growth.
(*e*) Defoliation.
(*f*) Crop weights and characters of fruits.
(*g*) Root systems.
(*h*) Effects of non-leaching treatment.

(*a*) *Times of opening of Leaf and Blossom Buds.*

The observations made under this heading were similar to those recorded for apple trees and gooseberry bushes, i.e., the break of both leaf and blossom

PLATE II.

Showing shoot growth and foliage characters of Black Currant bushes resulting from the different nutrient treatments.—July 31st, 1924.

buds was retarded in Series C, E, H, during the second and third seasons of the experiment, the stage of development in Series E, generally being a little ahead of that in Series C, H.

Thus on March 30th, 1924, in Series A, D, F, G, the terminal buds of the shoots had broken and reached the small leaf stage, whilst in Series E, C, H, the leaves from the terminal buds were not fully open and the lateral buds still appeared to be in the dormant stage.

(*b*) *Blossom Characters.*

Here also it is only necessary to state that blossoming in Series, E, C, H, became much restricted as early as 1923, the second season of the experiment, and that the flowers in these series were very weak.

Blossom counts were not made but extent and character of blossoming is reflected in the cropping data for that season given in Table IX.

(*c*) *Foliage Characters.*

Series A.—As with apples and gooseberries, the foliage in this series was plentiful and the leaves were of normal size and colour.

Series C.—Even in the first year of the experiment the foliage was very sparse, the leaves being small and pale yellowish green in colour. They developed strong red tints during the last week in July.

In 1923, 1924, the foliage was practically confined to the tips of the shoots whilst the leaves were very small and showed much yellowing. Intense red tints were developed as early as June 30th in 1923 and by May 31st in 1924.

Series D.—The amount of foliage on the bushes in this series was generally less in amount than in Series A from an early date in each season.

At the commencement of each season the bushes carried as much foliage as in Series A, and the character of the leaves in the two series was similar. However, after about one month from the time of bud break it was generally noted that the amount of foliage in this series had fallen behind that in Series A, and that this was due to the fact that the leaves along the shoots failed to develop to any size whilst where larger leaves were developed at any distance from the tips of the shoots these were generally shed. Thus the shoots from mid-season onwards always looked rather bare.

The leaves in general were smaller than in Series A, were darker green in colour and tended to droop towards the stems and to curl towards their under surfaces. Leaf scorch was not generally developed until the latter part of the season, which fact was probably due to the leaves failing to make good development.

Occasionally leaves developed symptoms of chlorosis between the veins in their marginal areas similar in appearance to those noted in the experiment on apple trees.

Series E.—In this series the treatment produced very marked and characteristic effects on the foliage of the bushes. In general, these effects were similar to those developed on apple trees and gooseberry bushes in that the amount of foliage became greatly reduced in the second season and eventually, in the third season, its development was confined to the tips of shoots, whilst leaf size was reduced and all the leaves developed very marked purple and bronze coloured tints. The effects produced on the leaves in this experiment differed from those with apple trees and gooseberry bushes in that the leaves in this experiment developed spotting much more extensively. The spots were generally purple when first developed but later became brown. They appeared simultaneously with the purple tints developed on the leaves.

The characteristic purpling and spotting were extensively developed in the three seasons by the following dates :—1922—July 28th, 1923—May 27th, 1924—May 24th.

Series F.—The foliage in this series was very similar in amount and character to that in Series A. As with gooseberry bushes, tints were occasionally developed on the leaves similar to those in Series G, but never to a marked extent.

Series G.—The amount of foliage developed in this series was similar to that in Series A, whilst leaf size was also similar in the two series. Very characteristic tints were developed on the leaves in each season. In the early stages of development, these took the form of reddish purple patches shaped as the leaves and extended over practically the whole of the leaf surfaces, leaving normally green marginal bands approximately one quarter to half an inch in width around them. The colour gradually deepened until it became an intense purple after which the tinting spread over the whole of the leaf areas. The edges of the leaves at this stage became curled towards their under surfaces and eventually the leaves became dried out and were shed. The appearance of the bushes at the purple stage of tinting was very striking in contrast to the tints developed in the other series. The purpling stage was first reached in 1922 by September 18th and in 1923 and 1924 by July 18th.

Series H.—As in the previous experiments, the amounts of foliage and nature of the tints developed on the leaves were similar to those in Series C, the tints developed being somewhat redder than in that series.

(*d*) *Shoot Growth.*

Data obtained for the bushes which received the leaching treatment but which were not root pruned at the end of each season are presented in Table VIII.

TABLE VIII.

SHOOT GROWTH OF BLACK CURRANT BUSHES, SEASONS 1922—1924.

	Season 1922.					Season 1923.				Season 1924.		
Series.	No. of bushes.	Total shoot growth. mms.	Average per bush total shoot growth. mms.	Length of longest shoot. mms.	Type of shoot.	No. of bushes.	Total shoot growth. mms.	Average per bush total shoot growth. mms.	Length of longest shoot. mms.	No. of bushes.	Total shoot growth. mms.	Average per bush total shoot growth. mms.
A.	10	7510	751.0	180	Normal	8	25995	3249.3	465	8	24885	3110.6
C.	10	2520	252.0	105	Thin	8	1530	191.3	125	8	1110	138.7
D.	10	5185	518.5	165	Normal	8	16915	2114.4	410	7	15680	2240.0
E.	10	7205	720.5	190	Thin	8	3785	423.1	160	8	4715	589.4
F.	10	7540	754.0	180	Normal	8	22300	2787.5	410	8	25065	3133.1
G.	10	8620	862.0	215	Normal	8	21520	2690.0	475	8	24035	3004.4
H.	10	2550	255.0	95	Thin	8	505	63.1	50	8	980	122.5

Examination of these shows that they are similar in character to those obtained for apple trees and gooseberry bushes.

Thus, in the first season shoot growth was restricted seriously only in Series C, H, whilst in subsequent seasons it was also greatly restricted in Series E. It was also somewhat restricted in all seasons in Series D. The shoots in Series C, E, H, were much thinner than those in the other series from the first season. Typical examples of shoots taken from plants in the various series on December 2nd, 1924, which illustrate the condition of these after three seasons of treatment, are shown on Plate III.

(*e*) *Defoliation.*

The treatments given in Series C, E, H, as in the previous experiments produced very early defoliation after the first season. The bushes in Series D, F, G, became defoliated simultaneously with those in Series A, although in Series D, partial defoliation generally occurred during mid-season. Treatment G, did not affect the time of defoliation of the plants to any appreciable extent.

The following notes will serve to show the progress of defoliation during the three seasons.

Season 1922.—Defoliation in Series A, D, F, G, took place over the period October 17th—November 15th ; in Series E from August 26th—November 7th ; in Series C from July 28th—November 7th ; in Series H from July 28th—October 31st.

Season 1923.—There was some defoliation during a hot spell around August 13th in all series. In Series C, E, H, only tip foliage was retained after this period. Defoliation was complete on the following dates :—Series A, D, F, G—November 20th ; Series C, E—October 22nd ; Series H—October 14th.

Season 1924.—Defoliation commenced as early as May 28th in Series E, and on June 27th in Series C, E. These three series were practically defoliated by August 16th. Defoliation took place in Series A, F, G, between August 16th and October 31st and in Series D, from August 9th to October 31st.

During defoliation tints were developed in the various series as follows :—

Series A.—Orange and red tints.
Series C, H.—Intense red tints with some orange tints.
Series D.—Brown marginal leaf scorch and a few yellow tints.
Series F.—As in Series A, but rather deeper red tints.
Series G.—Intense purple tints with occasional orange tints.

(*f*) *Crop Weights and Characters of Fruits.*

Crop weights were recorded in 1923 only, as in 1922 all blossom was removed so as to obtain reliable data for shoot growth whilst in 1924 the " set " was

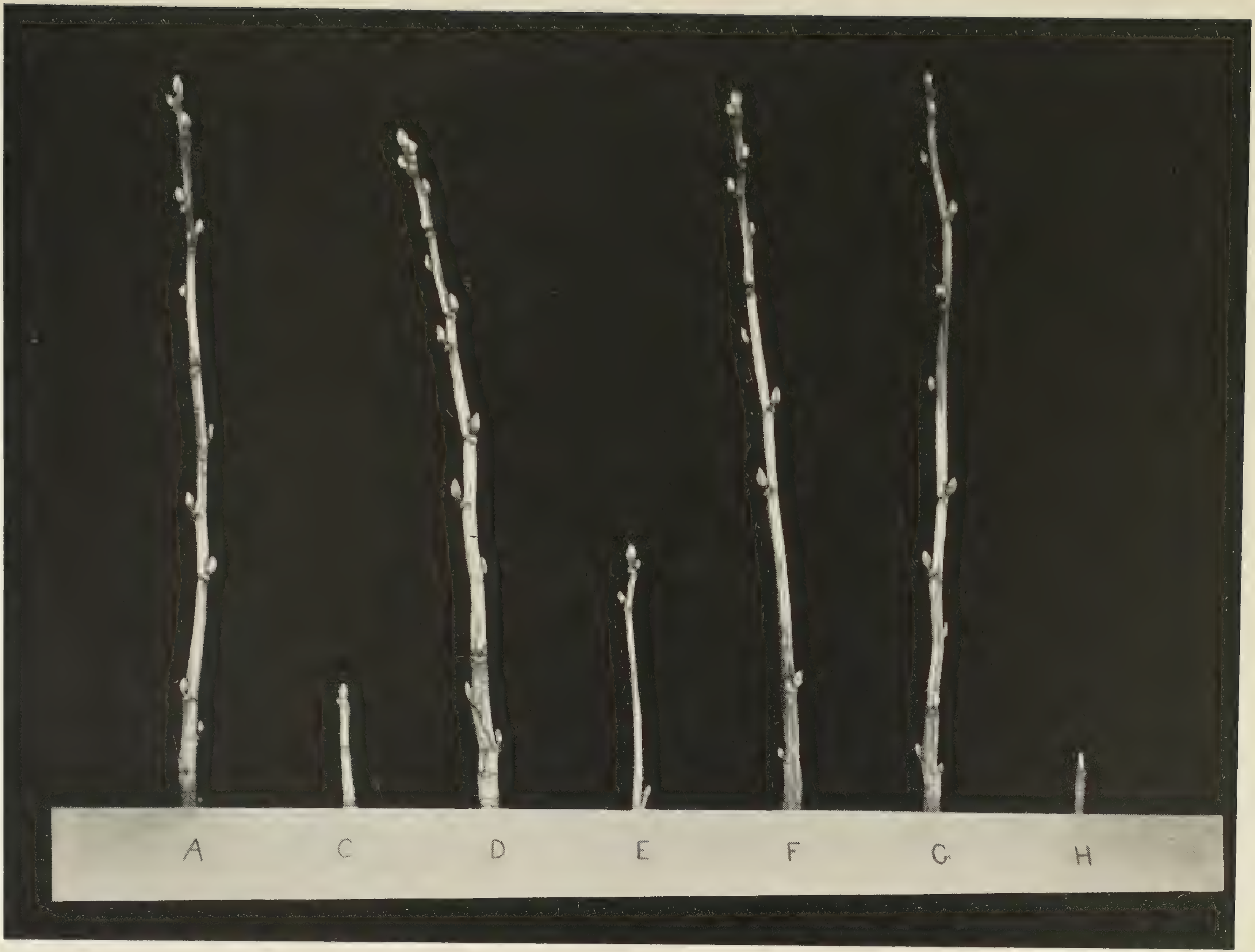

PLATE III.

Illustrating comparative shoot growth of Black Currant bushes after three seasons of treatment.

spoilt by the dry atmospheric conditions obtaining in the orchard house in which the bushes were housed during the period of blossoming. The data obtained are presented in Table IX.

TABLE IX.

Cropping of Black Currant Bushes.—Season 1925.

Series.	No. of bushes.	Total number of fruits.	Total weight of fruits. Grammes.	Average weight per fruit. Grammes.
A.	10	828	497·5	0.60
C.	10	113	34·7	0.31
D.	10	644	257·7	0.40
E.	10	381	113.8	0.30
F.	10	1076	611.3	0.57
G.	10	951	536.0	0.56
H.	10	105	33·6	0.32

It will be seen from these data that the treatments C, E, H, had exercised very significant effects on cropping after one season. The total yields in these series were much below those in the other series, whilst the actual weights of the individual fruits were considerably reduced.

As with gooseberries, the fruits in Series E, differed appreciably in flavour from those of the other series, being much more acid to taste.

(*g*) *Root Systems.*

The root systems of two bushes per series were examined on December 20th after one season's growth. These bushes were root pruned previous to replanting in the pots. This treatment is being repeated each season.

On the occasion of the first examination the root systems in Series A, D, F, G, were similar in appearance. They were large and well developed and had plenty of healthy coarse roots and an abundance of fine fibre. There was much recent growth in all cases.

In Series C, E, H, the root systems were similar in size, being much smaller than in Series A, etc. Those in Series E, were slightly larger than those of Series C and H, and in these latter series the fibre was brown in colour.

The examination of the root systems of these plants was carried out at the end of the second season on January 1st, 1924.

As on the previous occasion there was great reduction in the sizes of the root systems in Series C, E, H, as compared with those in the other series. The fibre of the roots in Series C, H, was very thin and of starved appearance and there was much browning of fibre in Series H. In Series E, the primary

roots were thin and short, and the secondary fibre was poorly developed. The roots were brown in colour.

Of the other series, the root systems in Series A, were well developed ; in series D, they were also fairly well developed but the fine fibre was rather short ; in Series F, the coarser roots were shorter than in Series A ; in Series G, the coarse roots were well developed but the fine fibres were very short and the tips were blackened as though injured.

(*h*) *Effects of non-leaching.*

The results obtained in this experiment were similar to those obtained in the experiment with gooseberry bushes, i.e., the growth period was lengthened and the autumn tints developed were not so bright as those developed by the leached plants.

Summary of Results on Blackcurrant Bushes.

1. The times of opening of leaf and blossom buds were delayed in Series C, E, H.
2. Blossom development was much restricted in Series C, E, H, in the second season of the experiment.
3. Characteristic types of foliage were produced by each treatment. The effects produced by the various treatments on the amounts of foliage carried were similar to those in the experiments on apples and gooseberries, as also were the characters of the tints produced by treatments C, D, E. H. Leaf scorch was not developed in Series D, so markedly as with apples and gooseberries. Very marked and characteristic tints were developed in Series G. Those developed in Series F, only differed slightly from those in Series A.
4. Shoot growth was much reduced in Series C, H, in the first season and also in Series E in the second season. It was somewhat reduced in Series D from the first season.
5. Defoliation was hastened from the first season in Series C, E, H.
6. Crop weights and size of fruits were greatly reduced by treatments C, E, H in the second season of the experiment.
7. Root growth was only restricted to any extent during the first season in Series C, E, H. Certain effects on the root systems in the other series were observed at the end of the second season.

Experiment with Raspberry Plants.

The variety used was Pyne's Royal. The canes were planted in the pots on March 14th, 1923. Previous to planting all fibre was removed from the roots and the canes were cut down to a length of about six inches.

There were ten plants in each series and the nutrient treatments given were as in the previously described experiments. The tops of the pots were covered with loose pieces of tarpaulin during part of the first season but it soon became necessary to remove these altogether owing to the continuous development of new canes during the season. During the whole of the second season covers were never used. The pots were always kept under a glass-roofed shed with open sides to protect them from rain.

Data relating to the following points were obtained :—

(*a*) Nature of spring growth.

(*b*) Foliage characters throughout the season.

(*c*) Shoot growth.

(*d*) Defoliation.

(*a*) *Nature of Spring Growth.*

In 1923 there was very little difference in the growth of the plants in the different series until May 4th, when some effects of the treatments became apparent in Series C, D, H.

On this date, the growth of the bushes in these series was slightly behind that in the other series whilst the foliage in Series C, H, was slightly pale with reddish tints and in Series D, it was a dull green colour.

As the canes formed in 1923 were cut down to the level of the sand in the pots at the end of that season, it was possible in the spring of 1924 to make observations on the development of new shoots.

The first observations of this latter season were made on April 6th, on which date new shoots were showing in all series excepting Series C, H. From this date until the end of April shoot development in Series C, H, E, was much behind that in the other series in which growth was very similar. By May 7th, the growth in Series D had fallen behind that in Series A and was similar to that in Series E. Series F, G, continued to make growth similar to that in Series A. Thus on May 19th the length of the shoots in the various series was as follows :—

Series A, F, G.—Canes ranged from twelve to eighteen inches high ; Series D, E—from nine to twelve inches high ; Series C, H—from bud growths to nine inches high.

(*b*) *Foliage Characters throughout the Season.*

Series A.—The foliage in this series was well developed and of normal character during both seasons. The leaves were large and green.

Series C.—The amount of foliage in this series was much less than in Series A from an early date in the first season whilst during the second season the plants only carried a little poorly developed tip foliage.

The leaves were small and exhibited yellow and red tints from an early date in each season. During mid-season many of the leaves were practically white or pink in colour, all green colour practically disappearing from them.

Series D.—The foliage in this series was poorly developed in each season, the leaves being small and dull green in colour with a tendency to develop browning between the veins and around the margins whilst they became very much curled back towards their under surfaces and did not stand out horizontally from the canes but exhibited very decided drooping. These characters became evident from an early date even in the first season. The marginal brown scorch was first noted on July 7th in 1923 and on July 16th in 1924.

Series E.—The amount and character of the foliage was normal during the first season until August 3rd when the colour became rather dull, which change was followed by bronzing. After the appearance of these tints the quality of the foliage quickly deteriorated.

During the whole of the second season the foliage was very sparse, being generally confined to the upper portions of the canes whilst the leaves were dull green in colour and showed marked bronze tints. As in Series D, the leaves became much curled and drooped towards the canes.

Series F.—The amount of foliage and the leaf characters in this series were generally very similar to those in Series A, though at certain times during the Summer the leaves looked rather paler than in the latter series.

Series G.—As in other experiments, the foliage in this series showed some very characteristic features.

The amount of foliage and the size of leaf were similar to Series A.

In 1923, the leaves commenced to develop yellow tints about July 14th and by August 13th a large proportion of the foliage showed these tints very strongly.

The tinting developed in a very characteristic fashion. First of all a fairly large patch in the centre of the leaf and shaped roughly like the leaf turned yellow, a fairly broad band around the margin remaining green. This was followed by the development of a narrow yellow band around the outside edge of the green band leaving a narrow green band between the two yellow areas. When this stage was reached the leaf became flaccid and soon dried out.

The tints were present on the older leaves by June 7th in 1924, and by July 26th they were strongly developed on most of the foliage and many leaves had then reached the flaccid stage.

Series H.—The amount of foliage and character of the leaves in this series was very similar to that in Series C, the amount of foliage being very

small whilst the leaves were small and highly tinted. The tints were generally not so yellow as in Series C, whilst the red colours developed were more pronounced.

(*c*) *Shoot Growth.*

The data obtained relating to the shoot growth of the plants during the two seasons are presented in Table X.

TABLE X.

Shoot Growth of Raspberry Plants.

	Season, 1923.					
Series.	No. of plants.	Total No. of shoots.	Total length of shoots. mms.	Average length of shoots per plant. mms.	Total weight of shoots. gms.	Average weight of shoots per plant. gms.
A.	10	16	10780	1078.0	114.9	14.49
C.	10	17	5300	530.0	28.5	2.85
D.	10	16	6150	615.0	37.7	3.77
E.	10	12	8006	800.6	73.1	7.33
F.	9	13	6180	686.7	42.5	4.72
G.	10	19	8500	850.0	57.1	5.71
H.	10	14	3990	399.0	19.1	1.91
	Season 1924.					
Series.	No. of plants.	Total No. of shoots.	Total length of shoots. mms.	Average length of shoots per plant. mms.	Total weight of shoots. gms.	Average weight of shoots per plant. gms.
A.	10	58	27630	2763.0	346.3	34.63
C.	10	21	2115	211.5	11.5	1.15
D.	10	41	14580	1458.0	139.3	13.93
E.	10	28	11015	1101.5	111.2	11.12
F.	7	32	17510	2501.4	209.2	29.89
G.	10	39	23610	2361.0	296.9	29.69
H.	10	24	2310	231.0	10.5	1.05

Examination of these data show that in the first season shoot growth was greatly restricted by the treatments in Series C, D, H, to a less extent in Series F, and to a small extent in Series E, G, whilst in the second season the total amounts of shoot growth in Series C, H, was extremely small, in E, D, only poor and in F, G, fairly good though less than that in Series A. The numbers of shoots per plant formed in Series C, E, H, in the second season were small in comparison with the number per plant in the other series, which points to weak bud developments in these series as had been noted in the

previous experiments. It is worthy of note that in this experiment, as in those with apples, etc., shoot growth in Series E was not greatly affected during the first season but became greatly reduced in the second season.

The canes formed in Series C, D, H, during both seasons and in Series E in the second season were much thinner than those in the other series.

One point in connection with the rate of shoot growth of the plants in Series D requires mention.

During periods of bright weather these plants appeared to be unable to make any appreciable amount of shoot growth. Thus in season 1923, the amount of shoot growth in this series was extremely small until late summer when the rate of shoot growth increased and enabled the plants to make considerably longer growth for the season than those in Series C, H. Similar observations have been made in experiments with strawberry plants. (Page 23.)

(d) Defoliation.

Defoliation was hastened in both seasons by treatments C, E, G, H. Extensive observations were not possible in 1924 owing to some of the plants becoming severely attacked by red spider during the late summer of that season. The plants were sprayed to combat this attack on August 16th but unfortunately the application of the spray resulted in serious defoliation.

The following notes will serve to show the progress of defoliation during the two seasons.

Season 1923.

September 30th.—Series C—40 to 50 per cent. defoliation ; Series H—30 to 40 per cent. defoliation ; Series E—30 per cent. defoliation ; Series G—10 to 20 per cent. defoliation ; Series D, F—slight defoliation ; Series A—No defoliation.

October 22nd.—Series C, H, approximately 60 per cent. defoliated ; Series E—50 per cent. defoliated ; Series G—30 per cent. defoliated ; other series defoliation less than 10 per cent.

November 9th.—Series C, E, H, were defoliated ; Series D, G, retained only tip foliage and were slightly more defoliated than Series A, F.

Season 1924.

August 2nd—Series C, H had only tip foliage ; Series E, G were 50 per cent. defoliated ; Series A, D, F—practically no defoliation,—the foliage in Series A being in excellent condition, in Series D, showing severe leaf scorch and in Series F being in good condition, though affected to some extent by Red Spider.

It is worthy of note that defoliation was greatly affected from treatment G in this experiment, as in the experiment with apples.

The tints developed during defoliation were as follows :—

Series A.—Orange and red.

Series C.—Orange and red and rather more intense than in Series A.

Series D.—Yellow. Most leaves died down showing brown marginal scorch and brown markings between the veins.

Series F.—Orange and red.

Series G.—Yellow, as described for summer foliage, with some red.

Series H.—As in Series C, but red more intense and less orange.

SUMMARY OF RESULTS ON RASPBERRY PLANTS.

1. Shoot growth commenced later in Series C, E, H, than in the other series.
2. Definite foliage characters resulted from the various treatments. The relative amounts of foliage produced in the different series were generally similar to those in the experiments with apples, etc., the amounts in the second season being very small in Series C, E, H, much reduced in Series D, and only slightly reduced in Series F, G.

   The tints developed in Series C, E, H, were similar to those in previous experiments and leaf scorch resulted from treatment D. In Series G, very definite leaf symptoms were produced. The leaves in Series F did not show any marked differences from those in Series A.
3. Shoot growth was very small in Series C, D, H in the first season and also in Series E, in the second season. The shoots in these series were also much thinner than in the other series. The number of shoots was greatly reduced in Series C, E, H in the second season.
4. Defoliation was hastened in Series C, E, G, H.

EXPERIMENT WITH STRAWBERRY PLANTS.

THE variety used was Royal Sovereign. Ten plants per series were planted in the pots on December 11th, 1920, for the treatments A to H. In addition, two further series, labelled X and Y respectively, six plants per series, were commenced on this date. The plants in these two series were fed with solution A, but those in Series X were leached as in Series A, whereas those in Series Y were not leached.

The experiment was continued over the four seasons 1921—1924.

Data relating to the following points were obtained :—

(*a*) Growth and foliage characters during spring, summer and autumn.

(*b*) Time of blossoming.

(*c*) Crop weights and characters of fruits.

(*d*) Effects of non-leaching treatment.

(*a*) *Growth and foliage Characters during Spring, Summer and Autumn.*

Series A.—The plants in this series made good growth during the first three seasons of the experiment and behaved in every way in normal fashion. They started into growth strongly in the early spring and continued to make good growth until the period of fruiting in June, following which the foliage always appeared to indicate that the plants were in an exhausted condition until about the end of July. From this latter time the plants continued to develop much new foliage until growth slowed down for the season about the end of November.

The foliage during each season previous to fruiting was of a normal green colour, the leaflets being large and the petioles long and well grown. After fruiting, during the autumn period of growth, the plants were smaller than before fruiting but the foliage was normal in character.

The tints developed in autumn were mostly orange and red in colour.

During the fourth season the plants started into growth very slowly in the Spring and during the whole of the season the growth was very poor and the foliage looked exhausted. It is doubtful whether any of the plants will commence growth in 1925 and it appears that plants under these conditions will only grow satisfactorily for three seasons. This statement applies to the plants in all series.

Series C.—The plants in this series failed to make any appreciable growth from the outset and indeed, after the growth of the first spring had died down after the fruiting period, the plants were always smaller in size than they were at the time of planting.

The amount of foliage developed was always scanty, the leaflets being small and the petioles short and attenuated. The colour of the leaves was an extremely pale green from an early date each season and yellow and red tints were developed. The foliage developed after fruiting was very small in amount and died down early in the autumn.

The autumn tints were orange and scarlet.

Series D.—The plants in this series were very similar in appearance to those in Series A during the first season until September when it was noted that the younger foliage which was being developed was not so vigorous as in Series A, and was of a dull green colour. During the second and third seasons the plants started into growth quite as vigorously as in Series A, but towards the end of May they began to fall behind. The leaflets remained smaller and became dull green in colour, the petioles around the central crowns did not elongate as in Series A, and were thinner and this gave to the plants a characteristic squat appearance. After fruiting, the plants remained very small until about the end of August after which they usually made good growth and

finished up very little behind those in Series A in size of plant though the leaflets remained somewhat smaller and the colour was generally a duller green.

The behaviour of the plants in this series as regards growth during the season was thus similar to that of the raspberries undergoing similar treatment.

The plants did not develop an excessive amount of leaf scorch though this was generally in evidence in early July and during late autumn. The autumn tints were never so brilliant as in Series A, red being generally lacking and yellow and brown predominating.

The behaviour of the plants during 1924 was interesting. As in Series A, they started into growth only very slowly and remained small. After fruiting the older foliage died down and from this time until the end of August the foliage of each plant consisted of a cluster of tiny dwarfed leaflets carried on very short petioles. During September, until the end of the growing period the plants grew away somewhat from this dwarfed condition. The feature was not shown by the plants in any of the other series.

Series E.—The growth of the plants in this series fell greatly behind that in Series A during the first season. By the middle of September the plants were in very poor condition, the foliage appearing dull and showing much purple tinting. During the two subsequent seasons the growth of these plants was always behind that in Series A from a very early date. They appeared to start into growth later than those in Series A, and became only very poorly developed before fruiting. After the fruiting season there was a tendency for the plants to develop only single crowns, which condition was comparable with the lack of lateral bud development in apples, etc. The foliage from 1922 developed marked purpling and bronzing at early dates in the seasons. Thus purpling was strong by June 12th in 1922 and as early as April 28th in 1923. Previous to purpling the leaves were dull green in colour and red colourations were developed along the veins. Bronzing was generally very prominent during the fruiting period and the tinted foliage died down soon after its development.

The size of the plants in the series was generally considerably larger than those in Series C, H, but appreciably smaller than those in any of the other series.

During autumn, purpling developed on all new foliage at an early age and growth ceased sooner than in Series A. Orange and red tints were often developed in the late autumn.

In 1924, as in previous seasons, the growth made was smaller than in Series A.

Series F.—The plants in this series were generally very similar in size and character of foliage to those in Series A. They started into growth simultaneously with those in Series A. and during the early part of the growing season

the plants in the two series looked practically identical. In each season, by about the middle of June, the plants in Series F, were slightly larger than those in Series A, the petioles being longer and the leaflets rather larger. About this time the leaves were usually slightly paler green than in Series A, and reddish tints were sometimes developed.

After fruiting until the end of the season, the plants were generally very similar in size to those in Series A, being sometimes slightly larger. The tints developed were, as a rule, redder and more brilliant than in Series A.

During 1924, growth was poorer than in Series A.

Series G.—Growth in this series was smaller than in Series A in all seasons and the plants showed several characteristic features.

They were much smaller than in Series A during the early part of the growing season, both petioles and leaflets being smaller. During the latter part of June the plants generally became larger than in Series D, but the leaflets remained smaller than in Series A, and the plants appeared slightly squat owing to the short petioles. About this period the colour of the foliage became slightly pale and purple tints were developed. From this time tinting became very pronounced and developed along the lines described for Series G in the Raspberry experiment, i.e., on each leaflet there was a centre patch of colour and a marginal rim of colour, these two being separated by a narrow band which remained practically green until a late stage of the process. The tints were usually purple at first but later various shades of red and yellow appeared.

The new foliage developed after the fruiting period was characterised by very short petiole development and relatively small leaflets and as the petioles usually assumed a horizontal position the plants looked very small and squat.

Very high purple, red and orange tints, as above, were developed in the autumn.

Series H.—Throughout the period of the experiment the plants were very similar in appearance to those in Series C, but differed in that the tints developed were redder than in that series. At the end of the fourth season eight of the original ten plants were still living.

(*b*) *Blossom Data.*

Observations made each spring on the time of blossoming of the plants showed that this was much delayed in Series C, H, and to a less extent in Series E. These results are similar to those obtained in the previous experiments. Thus in 1922 the first flowers were open in Series A, by April 22nd ; on May 3rd in Series E, and not until May 13th in Series C, H.

In 1923 the first flowers were open in Series A on March 19th ; in Series E on April 28th ; in series H on May 13th ; in Series C on May 20th.

(*c*) *Crop Weights and Characters of Fruits.*

The crop weights were obtained for the first three seasons of the experiment. These are brought together and presented in Table XI.

TABLE XI.

Cropping of Strawberry Plants.—Seasons 1921-23.

Season.	Series.	No. of plants.	Total No. of fruits.	Total weight of fruit. grms.	Average weight of fruit per plant. grms.	Average weight per fruit. grms.
1921	A.	10	131	513.8	51.4	3.92
	C.	8	49	191.4	23.9	3.91
	D.	10	76	279.2	27.9	3.67
	E.	9	83	356.1	34.0	4.29
	F.	10	90	358.8	35.9	3.99
	G.	10	119	483.4	48.3	4.06
	H.	10	51	170.6	17.1	3.34
1922	A.	10	91	266.8	29.6	2.93
	C.	6	10	18.4	3.1	1.84
	D.	9	67	193.8	21.5	2.89
	E.	7	39	85.3	12.2	2.19
	F.	8	42	114.4	14.3	2.72
	G.	8	60	174.4	21.8	2.91
	H.	9	7	12.1	1.1	1.73
1923	A.	10	110	471.0	47.1	4.28
	C.	5	3	9.7	1.9	3.23
	D.	9	87	345.4	38.4	3.97
	E.	6	32	116.6	19.4	3.64
	F.	8	136	554.3	69.3	4.08
	G.	8	92	321.3	40.2	3.49
	H.	8	9	24.6	3.1	2.73
Totals 1921-23	A.		332	1251.6		
	C.		62	219.5		
	D.		230	818.4		
	E.		154	558.0		
	F.		268	1027.5		
	G.		271	979.1		
	H.		67	207.3		

Examination of the data shows that the crop weights were greatly reduced from the first season in Series C, H, and to a less extent from the second season in Series E. These reductions were due to decreases both in number and size of fruits. Significant reductions also resulted from treatments D, G, in which series the plants were also reduced in size and were not so fresh as those in Series A during the fruiting period.

It was very difficult to obtain clear cut results on the quality of the fruits by tasting as there were very considerable differences in quality among the fruits of any one series. It appeared however, that the quality of the fruits in Series E was always poor, the flavour often being very flat and unpleasant and rather similar to that of over-ripe fruit, whilst the fruits in Series D lacked acidity and were very sweet to taste.

(*d*) *Effects of non-leaching.*

Observations on the effects of leaching were made on the Series X, Y, and were only continued over season 1921 and the spring of 1922 as none of the unleached plants started into growth in the second season.

By September, 1921, there was a marked difference between the growth of the plants in the two series, the plants in Series X, receiving the leaching treatment, being much larger than those in Series Y. From the end of September the leached plants commenced to develop normal orange and red tints whilst those receiving the non-leaching treatment began to show very severe symptoms of leaf scorch. Subsequently, all the foliage in the latter series turned brown and dried out and the plants appeared to be dead. The plants in both series were left in the pots over the winter, the sand being kept moist by watering. In the following spring those in Series X started into growth in normal fashion but none of the plants in Series Y showed any signs of growth.

Thus these results obtained with strawberries differed from those obtained with black currants and gooseberries undergoing similar treatments, as in the latter cases the unleached plants made more growth than the leached. It should be noted, however, that with all plants where the non-leaching treatment was given there was a tendency to suppression of normal tints and to the development of leaf scorch.

Summary of Results with Strawberry Plants.

1. Growth in the early spring was very backward in Series C, E, H, and was very restricted in these series from the first season.

    The growth made by the plants in Series D, G, was also less than in Series A, growth in Series D being especially poor during mid-season. Growth in Series F was often larger than in Series A, the plants having long petioles and relatively large leaflets.

    In Series G, the plants frequently had very short petioles and had a very squat appearance.

    In Series E, there was a tendency for plants to have single crowns whilst in Series D dwarfed leafy types were produced.

2. Very characteristic tints were developed in each season in the various series. These were similar in character to those developed by other plants undergoing the respective treatments.
3. Blossoming was appreciably delayed in Series C, H, and to a less extent in Series E.
4. Fruiting was greatly reduced from the first season in Series C, H, to a less extent from the second season in Series E, and to a significant extent in Series D, G.
5. Non-leaching treatment resulted in the death of the plants after one season.

Experiments on Deficiency of Sulphur.

Experiments on sulphur deficiency were commenced on apple trees, variety—Cox's Orange Pippin, gooseberry and black currant bushes, varieties—Keepsake and Seabrook's Black respectively, and strawberry plants, variety—Royal Sovereign, in spring 1924. Five plants were used in each case. As these experiments are not in an advanced stage the results are reported here separately from those of other deficiency treatments.

The procedure followed in these experiments was as in the previous deficiency experiments with these plants. The solution used was made up from Solution A, by substituting chlorides for sulphates in equivalent amounts wherever the latter occurred.

Observations made during the one season over which the experiment has been in progress were confined to the following points :—

(*a*) Shoot growth.
(*b*) Foliage characters.
(*c*) Defoliation.

(*a*) *Shoot Growth.*

The indications were that shoot growth will be substantially restricted by the treatment in all cases.

(*b*) *Foliage Characters.*

Very definite types of foliage resulted from the treatment with all plants. During July and August the leaves turned very pale green and later there was much yellowing of foliage and brilliant orange and red tints were developed. The leaves of gooseberries and strawberries developed narrow red marginal bands.

In general, the condition of the foliage of the plants resembled that of plants growing under conditions of partial nitrogen starvation.

(*c*) *Defoliation.*

Defoliation was hastened in all cases and during the process the predominant tints produced were bright orange and red.

B.—Experiments on the Ratio of Nutrient Elements.

Experiment on the Ratio $\frac{\textit{Nitrogen.}}{\textit{Potassium.}}$

The reason for carrying out this experiment was that it had been observed in the previous experiments with apple trees that leaf scorch was developed to a very serious extent in Series D, where potassium was omitted from the nutrient solution, to a less extent in Series A, where the complete nutrient solution was used and that practically no leaf scorch was developed in Series C, where nitrogen was omitted from the nutrient solution. Further, in the experiments with gooseberries and black currants leaf scorch was only developed in Series D.

It thus appeared that a high $\frac{\text{nitrogen}}{\text{potassium}}$ ratio was conducive to leaf scorch development and as the question is one of great practical importance, it was considered desirable to carry out further experiments on the point.

Fifteen maiden apple trees, variety—Cox's Orange Pippin, were selected for the experiment. These were graded by weighing and divided into three series, each series consisting of five trees.

The trees were planted in the pots on February 14th, 1923, the roots and shoots being pruned at the time of planting as in the previous experiment with apple trees.

The general procedure was as in previous experiments, the leaching treatment being given. The nutrient solutions used were labelled A, R, and S, respectively and the series to which they were applied were marked with these letters.

Solution A, used in this experiment was the original Solution A ; Solution R was made from Solution A by cutting down the amount of sodium nitrate in that solution so as to reduce the amount of nitrogen in the solution to one half of the original amount ; Solution S contained the same amount of nitrogen as Solution A, but the amount of potassium was approximately trebled by substituting potassium salts for sodium salts in Solution A.

Growth Characters of the Trees.

By the end of May the foliage on the trees in all series was well advanced and the trees looked healthy. Shortly after this date the trees in Series R, began to show symptoms of the low nitrogen treatment, shoot growth and leaf size falling behind those in the other two series whilst the foliage became paler

green in colour. These conditions became more pronounced as the season advanced.

Shoot growth in the other two series was very similar but there were differences to be observed in the leaf characters. The leaves in Series S were generally rather larger than those in Series A and appeared to be more nearly a pure green colour than those in this latter series, in which the colour suggested a bluish shade of green when contrasted with the green in Series S.

During the latter part of the season the leaves of the trees in Series S became badly affected by a form of blotching which appeared identical with that developed on the leaves in Series G in the previous experiment with apple trees (Vol. 4, Nos. 3 & 4, page 17).

Observations on Leaf Scorch.

Series A.—July 29th—slightly affected; August 6th—medium amount of leaf scorch present; August 11th—foliage badly affected. Serious defoliation, following leaf scorch, took place from this date.

Series R.—September 8th—foliage slightly affected. From this date to the end of the season the foliage was always slightly affected but the extent of the trouble never became serious.

Series S.—No leaf scorch was developed during the whole of the season.

Discussion.—From these results it will be seen that the most serious leaf scorch occurred in Series A, whilst only slight leaf scorch was present in Series R and that leaf scorch was entirely absent in Series S.

These observations indicate that it is essential in feeding apple trees not to have the ratio $\frac{\text{nitrogen}}{\text{potassium}}$ too wide or a condition analagous to potassium starvation will result.

Experiments on the Ratio $\frac{\textit{potassium}}{\textit{magnesium}}$.

In the previous experiment on $\frac{\text{nitrogen}}{\text{potassium}}$ ratio, it was observed that in Series S, where the amount of potassium in the solution was relatively high, the leaves developed symptoms which indicated a condition of magnesium starvation.

In order to test whether the increase of potassium was bringing about such a condition, it was decided to carry out further experiments in 1924 with apples, black currants and gooseberries.

Some of the plants in these experiments were to be fed with Solution S, with relatively high potassium content, and others with a Solution K, containing the same amount of potassium as in Solution S, but in which the amount of

magnesium was three times that contained in Solution S. The ratio of $\frac{\text{potassium}}{\text{magnesium}}$ in Solution K was approximately the same as that in the original Solution A.

Five one-year old plants per treatment were used in the cases of black currants and gooseberries whilst in the case of apples only five trees were planted for Series K treatment as material receiving Solution S treatment was already available for comparison. The varieties used were as follows :—

Apples—Cox's Orange Pippin ; gooseberries—Keepsake ; black currants—Seabrook's Black.

The trees and bushes were planted on April 5th, the procedure being as described for previous experiments.

Observations made.

Apple trees. The foliage in Series K, during the season, became affected with " blotch " to a slight extent but never to the degree of that on the trees fed with Solution S, where blotch was very severe and led to much premature defoliation. Shoot growth and leaf size were smaller in Series K than in Series S.

Gooseberry bushes.—There was a very marked difference between the foliage of the bushes in the two series from July 16th to the time of defoliation. On July 16th the foliage of all the plants receiving Solution S was showing marked symptoms, identical in character with those associated with magnesium deficiency, whilst that in Series K was fresh and green.

Eventually two plants in Series K developed the symptoms but these were never strongly marked. During the latter part of the season the foliage in Series S became very poor whilst that in Series K remained normally green. Defoliation took place at an earlier date in Series S than in Series K, the plants in the former series having lost approximately 40 per cent. of their summer foliage by October 22nd, whereas on that date in the latter series the plants had not lost 20 per cent. of their foliage.

Black Currant Bushes.

The plants in both series made excellent growth throughout the season and there were no differences in the appearance of the plants until August 23rd. On this date it was noted that the older foliage of the plants receiving Solution S was dying down more quickly than that of the plants receiving Solution K.

From this date defoliation proceeded more quickly in Series S than in Series K, whilst the plants in the former series also showed much more purpling of the foliage,—the symptoms associated with magnesium deficiency,—than did those in the latter series.

Discussion.

With all three test plants the tendency during the season was for the foliage of the plants receiving Solution S, with the high $\frac{\text{potassium}}{\text{magnesium}}$ ratio, to exhibit symptoms identical with those resulting from magnesium starvation whereas those receiving Solution K, with a lower $\frac{\text{potassium}}{\text{magnesium}}$ ratio, did not show these symptoms to anything like the same extent.

It seems important to point out that the ratio $\frac{\text{potassium}}{\text{magnesium}}$ may be of importance in apple and raspberry growing in cases where dung is not procurable and the grower has to rely solely on the use of artificial manures, as with these plants magnesium deficiency results in very serious premature defoliation.

The importance of using magnesium carrying fertilisers under such conditions in tobacco growing and the part played by potassium fertilisers in the problem has been pointed out (12).

Strawberry plants also appear to suffer badly under certain conditions when receiving a diet low in magnesium.

SUMMARY.

1. Present day problems relating to the manuring of fruit trees as they affect the grower are discussed.
2. Some results obtained in past field experiments on the manuring of tree and bush fruits are summarised and the present need for laboratory work on the fundamental principles of the nutrition of fruit trees is shown.
3. The programme of laboratory work on the nutrition of fruit trees, contemplated at this Station, is outlined.
4. The methods adopted in conducting nutritional experiments in sand cultures on apple trees, gooseberry bushes, black currant bushes, raspberry plants and strawberry plants are described.
5. Results obtained in deficiency experiments carried out during the seasons 1921—1924 with apple trees, gooseberry bushes, black currant bushes, raspberry plants and strawberry plants, in which the effects of deficiencies of nitrogen, potassium, phosphorus, calcium, magnesium and sulphur respectively were studied, are presented.
6. Data are presented in these experiments relating to shoot growth, cropping and nature of root systems and observations on blossom formation, foliage characters and time of defoliation are reported.

7. It is shown that deficiency of any one of the above elements produces characteristic effects on the various plants and the view is expressed that some of these may be of use for diagnostic purposes in the field.
8. Experiments are described in which it is shown that the ratios $\frac{\text{nitrogen}}{\text{potassium}}$, $\frac{\text{potassium}}{\text{magnesium}}$ in the diets of fruit trees are of importance.

ACKNOWLEDGMENT.

The writer wishes to acknowledge his indebtedness to Mr. W. H. Neild, Experiments Officer at this Station, for his invaluable assistance in the supervision and carrying out of the immense amount of routine work entailed in these experiments.

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Description of Plates.

Plate I.

Fig. A. Shoot growth and foliage characters of Gooseberry bushes undergoing various treatments—July 31st, 1924.

Note the poor growth and sparsity of foliage in the series "omitting nitrogen," "omitting phosphoric acid," "rain water only." Growth is also below normal in "omitting potash" series.

Fig. B. Root systems of Gooseberry bushes, showing the condition of the roots in January, 1924, after two seasons of treatment.

Plate II.

Shoot growth and foliage characters of Black Currant bushes undergoing various treatments—July 31st, 1924.

Note the poor growth and sparsity of foliage in the series "omitting nitrogen," "omitting phosphoric acid," "rain water only." The foliage in the series "omitting potash" is also relatively sparse.

Plate III.

Typical shoots of Black Currants after three seasons of treatment.

Note the weak growth of shoots and buds in Series C (nitrogen omitted), Series E (phosphoric acid omitted), Series H (rain water only).

A SURVEY OF INVESTIGATIONS BY AMERICAN HORTICULTURISTS ON CARBOHYDRATE-NITROGEN RELATIONS.

By HENRY D. HOOKER.

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The investigation of carbohydrate-nitrogen relations which has been carried on by a number of American horticulturists during the course of the past five years was originally undertaken by Kraus and Kraybill (13) in connection with a study of the factors associated with the vegetative and reproductive states. Klebs had found that plants remained vegetative in bright light with a plentiful supply of water and nutrients or in moderate light with a moderate supply of water and nutrients, and that they blossomed after growing in bright light with a moderate supply of water and nutrients. Benecke had pointed out that limitation of the nitrogen supply and increase of the phosphorus supply might favour blossoming. The formation of organic substances by carbon assimilation and the absorption of nutrients, especially nitrogen, were evidently factors influencing the development of the reproductive state, and the relation between these factors was apparently of particular significance. Kraus and Kraybill attempted to correlate vegetation and reproduction directly with the amounts of carbohydrate and of nitrogen within the plant, or rather with some relation between these amounts, analogous to the relation between carbon assimilation and nutrient absorption. By thus interpolating the chemical composition of the plant as a factor intermediary between the action of the environment and the response of the plant, the problem assumed two new phases: the effect of environmental change on the carbohydrate-nitrogen relations within the plant and the correlation of these carbohydrate-nitrogen relations with the vegetative and reproductive states. Both of these phases of the problem have received attention. Manuring, girdling, defoliation, illumination, shading and pruning have been studied as they affect the relative amounts of carbohydrate and of nitrogen in the plant and these carbohydrate-nitrogen relations have been investigated in connection with fruitfulness, flower-bud differentiation, sex differentiation, fruit set, vegetative growth and the development of roots from cuttings. It will be convenient to discuss first the effect of carbohydrate-nitrogen relations on reproduction and vegetation.

Kraus and Kraybill (13) working with the tomato found the most fruitful plants moderately low in nitrate nitrogen and total nitrogen and high in free reducing substances, sucrose and polysaccharides. Fruitfulness was associated neither with highest nitrates nor with highest carbohydrates, but with what the

authors termed a condition of balance between them. This condition of balance was interpreted by Crocker (2) as a ratio between carbohydrate and nitrogen, fruitfulness supposedly being correlated with certain values of this ratio, and Gurjar (4) went so far as to give definite ratios for vegetation and for reproduction in the tomato. Nightingale (16) concluded from experiments on tomatoes, salvia, buckwheat, soybeans and radishes that the relation of carbohydrate to insoluble nitrogen was more significant in connection with fruitfulness than the relation to total nitrogen. His plants were fruitful only when they contained an abundance of insoluble nitrogen and an abundance of carbohydrate. Although nitrates were stored under certain conditions, their presence did not affect the type of development. Work (22) was unable to find that either high or low carbohydrate inhibited reproductive activities in the tomato, but his samples were not selected in a manner likely to reveal a connection between carbohydrate-nitrogen relations and fruitfulness. He pointed out the desirability of collecting samples for analysis at brief intervals as the plants passed from one stage to another.

An investigation of this type on apple spurs (8) had shown the carbohydrate-nitrogen relations associated more specifically with the process of flower-bud differentiation. The seasonal changes in the chemical composition of apple spurs were followed through the usual two year cycle and the carbohydrate-nitrogen relations were determined at the time of bud differentiation in spurs which were bearing and so would not form flower buds, and in non-bearing spurs which might be expected to differentiate them. The non-bearing spurs had less total nitrogen and reducing sugars and more starch and hydrolyzable polysaccharides. Starch accumulation in appreciable quantities occurred at this time only in spurs which were presumably differentiating flower buds. This emphasized the significance of carbohydrate-nitrogen relations at the particular time when buds were ready to become differentiated. Obviously flower-bud differentiation cannot be induced if there are no buds to become differentiated or if the buds have already become leaf buds. Klebs had made this point in discussing the influence of external conditions on flower formation. Starch-nitrogen relations characteristic of flower-bud differentiation and of leaf-bud differentiation were found on the same tree, showing that separate parts of a plant may act independently and that flower-bud formation is associated with local carbohydrate-nitrogen relations. These observations were corroborated in the main by Harvey (6), who found higher percentages of flower-bud formation on spurs associated with relatively lower nitrate nitrogen, soluble nitrogen, total nitrogen and reducing sugars and higher hydrolyzable polysaccharides. However, his data did not indicate an exact correlation between fruit-bud formation and a mathematical carbohydrate-nitrogen ratio. Kraybill (14) examined the carbohydrate-nitrogen

relations in the last two years' growth of apples and in the last year's growth of peaches. He found markedly higher percentages of flower-bud formation associated with lower soluble nitrogen, insoluble nitrogen and total nitrogen and higher reducing substances, sucrose, starch and acid hydrolyzable polysaccharides. Smaller amounts of insoluble nitrogen were not accompanied by reduced flower-bud formation. The available data indicate clearly that flower-bud differentiation is invariably associated with carbohydrate accumulaation in the vicinity of the bud previous to the time of differentiation, starch storage being a striking index of this accumulation in the apple and peach.

This idea has been extended by Gardner (3), who presented some evidence to show that the kind of flower buds formed may be associated with the amount of carbohydrate accumulated. The production of perfect flowers in the strawberry was found to be accompanied by a higher carbohydrate and a much higher starch content at the time of flower-bud differentiation than the formation of pistillate flowers only. Gardner concludes after reviewing the literature on sex reversals in vascular plants that the differentiation of staminate flowers or of staminate parts is probably associated with greater carbohydrate accumulation than the formation of pistillate flowers or of pistillate parts in plants that exhibit variations in the sexual state.

The process of fruit setting has been correlated with carbohydrate-nitrogen relations by Murneek (6). In apple spurs a close correlation was found between the total nitrogen content at the time of the early drop and the number of fruits per spur. Setting was correlated with low values of the carbohydrate-nitrogen ratio, but the higher ratios associated with poorer set were produced by decreasing the nitrogen rather than by increasing the carbohydrate. Murneek pointed out that according to Kraus and Kraybill's data (13) the parts of the tomato plant closest to the setting fruit were relatively high in nitrogen, and that Hooker (8) reported a maximum of nitrogen in bearing apple spurs at the time of fruit setting. Howlett (12) found that young apples which were remaining on the tree contained nearly three times as much nitrogen per fruit as those which were going to drop and that there was not only a percentage decrease but an actual loss of nitrogen per fruit in the latter. On the dry weight basis the young fruits destined to drop contained distinctly more reducing substances, though the individual fruit contained less because of its smaller size. It seems fairly well established, therefore, that two of the most significant steps in the development of a fruit crop, namely, flower-bud differentiation and fruit set, are usually associated with carbohydrate-nitrogen relations directly contrary to each other.

The study of carbohydrate-nitrogen relations in connection with vegetative development has been more or less incidental to the study of fruitfulness, but the results obtained are in many respects more decisive. Kraus and

Kraybill (13) found that either the limitation of nitrates or the limitation of carbohydrates resulted in a suppression of growth in tomatoes. When carbohydrates and nitrogen were adjusted relative to one another, rapid vegetative extension resulted. Where carbohydrates were in excess such an adjustment was secured either by increasing the nitrogen without decreasing the carbohydrate or by decreasing the carbohydrate without increasing the nitrogen. In both cases the relation of carbodydrate to nitrogen would be the same, but the total amounts were greater in the former and less in the latter, a condition reflected in the amount of growth resulting. These experiments demonstrated quite clearly that nitrogen and carbohydrate were used in a fairly definite ratio for vegetative growth. A carbohydrate-nitrogen ratio for vegetative development would seem to be a necessary condition for either carbohydrate or nitrogen becoming a limiting factor of growth. However, the ratio is not, presumably, confined to carbohydrate and nitrogen but includes water and the essential mineral elements as well, which combine with them in definite proportion for the building up of any given plant tissue. The emphasis that the carbohydrate-nitrogen ratio has received may depend on nitrogen being so often the limiting factor of growth under cultural conditions. It remains to be determined whether a relative excess of carbohydrate over nitrogen is any more significant in flower-bud formation than a relative excess over other essential elements.

If carbohydrate and nitrogen combine in definite proportion for vegetative growth, typical responses to variations from this proportion might be expected. These responses have been found in the type and relative amount of top and root growth. When nitrogen and carbohydrate were both low but in proper proportion the amount of growth was small but the type of growth was classed by Nightingale (16) as vigorously vegetative. Carbohydrate in excess of the ratio appears to retard growth of the tops and to alter its type. Kraus and Kraybill (13) found that tomato plants that were lacking in nitrates and low in total nitrogen with very large accumulations of reducing substances, sucrose and polysaccharides, were weakly vegetative and unfruitful. The unfruitfulness of this class of plants in spite of carbohydrate accumulation is associated with a marked reduction in vegetative development. This stunted growth might be attributed to the limiting action of the low nitrogen supply but Nightingale (16) showed that when the carbohydrate content of such plants was decreased new growth was produced, even without an external nitrate supply. Furthermore, the high carbohydrate plants grown by Kraus and Kraybill (13) produced vigorous new shoots when the tops were removed.

That the more moderate accumulation of carbohydrate associated with flower-bud formation is also accompanied by retardation of growth is well-known, though it might be hazardous to assert which of these associated phenomena

is cause and which are effects. Harvey (5) found that in Grimes apples a moderate reduction of the carbohydrate-nitrogen ratio was accompanied by an increase in the rate of shoot growth, and an increase in the ratio was accompanied by a decreased growth rate. In Spitzenburg, however, carbohydrate-nitrogen ratio and rate of growth varied in the same direction, indicating that each variety had a distinct ratio optimal for shoot growth.

These facts suggest the possibility of some connection between carbohydrate-nitrogen relations and the annual period of inhibited growth known as the rest period. This has been investigated by Abbott (1) who found that the beginning of the rest period in young apple and peach trees was associated with carbohydrate accumulation and that it was delayed by treatments that lead to a reduction of carbohydrate content. Rosa (18) found immersion in sodium nitrate solution an effective means of abbreviating the rest period in the potato and he emphasised the action of rest-breaking agents on the enzymatic oxidation of carbohydrates. Hodgson (7) observed that starch disappeared from pear, peach and cherry buds in direct proportion to the duration of etherisation, both when the buds were kept warm and allowed to grow and when growth was inhibited in a cold room.

Starring (19) found the excessive accumulation of carbohydrate that is associated with yellowish colour and lack of vegetative vigor particularly favourable to root formation from cuttings of tomato and *Tradescantia virginiana* and Loomis (15) found the more rapid establishment of hardened (but not stunted) tomato, cabbage and cucumber plants correlated with carbohydrate reserve and new root formation.

The retardation of top growth and the stimulation of root development associated with carbohydrate accumulation suggests as a corollary that top growth may be stimulated and root growth retarded by nitrogen in relative excess over carbohydrate. In spite of the apparent horticultural importance of this question, little attention has been given it. However, Turner (20) reported that increasing the nitrate supply increased the ratio of tops to roots in barley and corn, though not in flax, and he attributed this increased ratio to greater carbohydrate utilisation in the tops. Starring (19) showed that the nitrate content of the plant influenced the proportion of tops to roots and that a high nitrate content depressed root formation from cuttings.

Since carbohydrate-nitrogen relations have been shown to be so intimately associated with vegetative and reproductive performance, the various means that are effective in controlling carbohydrate-nitrogen relations become matters of practical interest. Mention of the various treatments that influence the carbohydrate-nitrogen balance within the plant has been reserved until now to facilitate discussion, though the investigation of these procedures has been in most cases a necessary precursor to the work already cited.

Manuring with nitrate of soda or with other nitrogen fertilisers usually increases nitrogen and decreases carbohydrate. This is so often the case that Kraus and Kraybill (13) endeavoured to establish an inverse relation between nitrogen and carbohydrate in the tomato. However, Work (22) was able to show that the carbohydrate content could vary independently. A nitrate application may increase the nitrogen content of some parts of a plant and simultaneously decrease that of others. In young apple trees, for example, the nitrogen in the shoot tips was found to be greatly increased and the nitrogen in the middle of the one-year old wood to have been decreased six weeks after a nitrate application (11). Similarly a nitrogen application may eventually lead to greater carbohydrate content. Thus, an autumn application of nitrogen has been found to increase the starch content of apple spurs the following summer (10), though spring applications tended to reduce it (9).

Harvey (5) found that girdling increased sucrose, starch, pentosans, total hydrolyzable polysaccharides and total carbohydrate and decreased reducing sugars, phloridzin and nitrogen in apple trees. Kraybill (14) found increased starch, slightly more sugars and slightly less nitrogen a month after ringing and later samples showed increased insoluble and total nitrogen as well as increased carbohydrate. According to Kraybill, girdling prevented the translocation of carbohydrates to the roots and apparently did not inhibit the upward passage of nitrogen.

Defoliation has the reverse effect of girdling. Murneek (6) found that defoliation in April increased the carbohydrate-nitrogen ratio in apple spurs largely by decreasing the amount of nitrogen. Harvey (6) found that apple spurs defoliated in June and July contained more reducing sugar, nitrate nitrogen and total nitrogen and less hydrolyzable polysaccharides. Defoliation of apple shoots (5) increased the percentages of phloridzin and nitrogen and decreased sugars, starch, pentosans, total polysaccharides and total carbohydrates. Girdling and defoliation combined produced greater changes than defoliation alone, but they were of the same quality.

The effect of shading has been investigated by Kraybill (14). He found that shaded apple and peach trees contained more nitrogen, both soluble and insoluble, and less sugars, starch and hydrolyzable material than unshaded trees. Shading reduced carbon assimilation and increased nitrogen intake. Vinson (21) also reported a decreased carbohydrate-nitrogen ratio as the result of shading.

The influence of length of day on carbohydrate-nitrogen relations has aroused considerable interest since the discoveries of Garner and Allard. Nightingale (16) found that limiting the daily illumination to seven hours decreased the carbohydrate content and also the percentage of insoluble nitrogen while the amount of nitrates and other forms of soluble nitrogen

increased materially. In salvia, buckwheat, soybeans and radishes the formation of insoluble nitrogen was apparently restricted by the duration of light exposure, as starch and nitrate were present in abundance but insoluble nitrogen was not. In the tomato the formation of insoluble nitrogen was restricted by the carbohydrate supply rather than by the length of a six hour day. When tomato plants already high in carbohydrate were exposed to a shorter daily period of illumination, insoluble nitrogen was decomposed, though not to nitrates.

Recent investigations (11) on pruning showed that heading increased the percentage of nitrogen at the cut ends of apple shoots and lead to increased carbohydrate utilisation. Thinning conserved both the nitrogen and the carbohydrate supplies in the tree. Suppression of the leader by pruning was found to divert the supply of nitrogen to unpruned laterals.

It seems as if there were enough ways to regulate carbohydrate-nitrogen relations to meet any situation. Carbohydrate content can be increased by girdling, by thinning and by nitrogen applied at certain times ; it can be decreased by shading, by shortening the daily period of illumination, by defoliation, by heading and by manuring with nitrogen. Nitrogen content can be increased by manuring, by shading, by defoliation and by certain kinds of pruning ; it can be decreased by girdling or defoliation early in the season or by the local suppression of growth through pruning. Insoluble nitrogen can be decreased, in some plants at least, by shortening the length of day. Nitrogen content can be decreased also by depleting the supply with sod or intercrops.

The knowledge of the significance of carbohydrate-nitrogen relations and of how to control them cannot be said to have modified as yet any practice recommended for commercial orcharding. It has thrown light on many established practices such as manuring, training and pruning. It has accounted to some extent for conflicting results from certain treatments such as the summer pruning of apples (5). It has suggested a method for the correction of biennial overproduction in certain varieties of apples (17), though the practicability of this method has yet to be established. The record of past achievement is meagre, but the promise of future usefulness is great. This usefulness will probably develop in connection with problems of growth rather than of reproduction. Flower-bud differentiation is seldom a practical problem except in young trees and in certain alternate bearing varieties. A consideration of carbohydrate-nitrogen relations may, however, assist materially in stabilising pruning practice and in refining the technique of other orchard operations.

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BOOKS RECEIVED.

A List of British Aphides. J. Davidson, D.Sc., 1925, 176 pages. (Longmans, Green & Co., price 12s. 6d.) will receive a cordial welcome from horticultural entomologists. Since the issue in 1883 of the last volume of Buckton's classical monograph upon British Aphides there has been no comprehensive publication dealing with the nomenclature of this very important group of insects, with the result that the whole subject has reached a condition that can only be described as chaotic. Our old friend (or rather enemy) the Rosy Apple Aphis has, for instance, within the last ten years appeared as *Aphis sorbi*, *Aphis Kochii*, and *Aphis malifoliae*, and now it has found—permanently we hope—the name of *Anuraphis roseus*, Baker. Other familiar species have passed through similar vicissitudes to the annoyance of economic entomologists and the confounding of fruit-growers who have attempted to adopt a scientific nomenclature. Dr. Davidson's list now provides names which have the sanction of authority and although some further changes are likely to be necessary it is hoped that they will be few so that this list may prove a basis upon which to work for some years to come.

In addition to the pages devoted to the synonomy of the various species, there is also a list of general and a list of the different kinds of aphides which have been found upon the various cultivated and wild plants of the British Isles. Additions to the list will obviously be necessary, but again the existence of some basis upon which to work will be valuable.

It is perhaps hardly necessary to add that Dr. Davidson's book is not written for, and would not be of much use to, the practical fruit-grower, but it should be give an impetus to the study of one of the most destructive groups of insects and so will indirectly benefit horticulture at large.

THE PHYSICS OF SPRAY LIQUIDS.

V.—PARAFFIN—CRESOLS—SOAP SOLUTIONS: THE DETERGENT ACTION OF SOAPS.

By ROWLAND MARCUS WOODMAN,

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In a previous paper (1), reference was made to the preparation of paraffin-cresols-soap solutions; this paper deals with experiments to find the best proportions of the constituents so that the maximum amount of paraffin oil is *completely* dissolved on addition of certain amounts of water, the oil remaining in solution at all further dilutions.

Materials Used:

Cresols: the mixture of cresols used was bought as "pure cresylic acid" from a wholesale chemist.

Paraffin Oil: was a sample of "best" oil bought from a local pharmacy.

Soap: was a sample of "best" fish-oil soft soap (brown in colour) bought from a local pharmacy; it was kept in well-stoppered bottles to prevent drying. The soap contained 51.70 per cent. of actual potassium soap, being somewhat drier than the usual "genuine" soft soap (2).

No attempts were made to purify the above reagents, as a comparison with practical conditions was desired.

Experimental:

The solutions and mixtures of cresols-soap were made by triturating definite amounts of cresylic acid with definite amounts of the soap in a porcelain mortar; the volumes of the resulting solutions or mixtures were ascertained.

A definite amount of a cresols-soap solution was pipetted into a 250 c.c. measuring flask, and distilled water was titrated in from a burette in approximately 0.2 c.c. portions at a time, rotating and shaking the flask between each addition. The 250 c.c. flask was chosen as the titrating vessel because the contents could then be mixed thoroughly without the entanglement of much air, as the large surface of the liquid tended to produce evanescent foams only; thus more definite readings between slightly turbid mixtures and clear solutions were obtained. The amount of water added to cause complete solution (if it occurred), so that subsequent dilution did not affect the solution, was noted.

The same volume of the cresols-soap solution was then pipetted into 250 c.c. flasks, and differing amounts of paraffin oil added to each. The appearance of the resulting mixtures was noted, *e.g.*, whteher true solutions or mixtures, and then water titrated in, as before, to ascertain if a point existed where addition of *any* further amount of water gave solutions.

Before this final solution (if it occurred), took place, the flask's contents in all cases went through a sequence of stages, cloudy liquids, emulsions,

turbid mucilages, clear mucilaginous jellies and clear solutions all being obtained. The number of these stages was greatest in the case of cresols-soap solutions alone, progressive additions of paraffin oil tending to suppress more and more of the stages and thus make the titration simpler. In all cases the titrations ended with solutions of oil in water, or mixtures of solution and emulsion of oil in water, the mixture having a "buttery" appearance when much oil was dissolved, or being much whiter if the emulsion predominated. It was difficult to prove to what the stages corresponded; it was suspected that water-in-oil and oil-in-water emulsions were both being produced at different stages of the titration. Simple methods of differentiation such as indicator methods were of no use in such complicated systems as these, where a disperse phase of paraffin oil or possibly cresylic acid or mixtures of both, is suspended in a solution *saturated*, under the given conditions, with respect to paraffin oil or cresylic acid or mixtures of both. Future experiments will be done on these stages, with a new method of differentiation of the two possible types of emulsion which has been discovered.

It can, therefore, be said that the statement, given even in the most recent work on emulsions (3), with regard to an emulsion's being tiny particles of one liquid dispersed in an *immiscible* external phase, needs modification; Pickering (4) modified the statement, showing that the two phases might be soluble in each other, as long as the external phase is saturated with the internal phase, or the globules of internal phase prevented from dissolving in the continuous or external phase by reason of an absorbed layer. The present work emphasises the fact that the partial miscibility of two liquids, however great, is no bar to formation of an emulsion by the two liquids.

The results for the final solution of paraffin oil in different cresols-soap solutions are given in Table A.; the general observations got by diluting the mixtures greatly are tabulated in Table B.

It will be seen from Table A that two of the cresols-soap solutions are capable of dissolving completely large amounts of paraffin oil on addition of certain volumes of water, subsequent dilution not disturbing the solution. After doing these experiments, it was found that Pickering had a later paper (4) in which he shows that benzene and lighting oil are actually soluble in soap alone, giving solutions which may, or may not, dissolve completely on addition of water (no example of complete solubility of lighting oil on addition of water is given). His method of experiment was to mix definite amounts of soap and oils with a spatula and add water to the extent of nineteen times the amount of anhydrous soap present; he then allowed the resulting mixture of solution and emulsion of oil to cream, and analysed the creams for oil, thus finding, by difference, the amount of oil actually dissolved. Pickering undoubtedly missed the stages described above by adding his dilution water in bulk.

TABLE A.

Amt. of Fresh Soap in Mixture. (gm.).	Amt. of Cresols in Mixture. (c.c.).	Vol. of resulting Mixture. (c.c.).	Description of Mixture.	Amt. of cresols-soap taken (c.c.).	Amt. of Paraffin oil added. (c.c.).	Description of Mixture.	Actual amts. of Paraffin (c.c.), anhydrous soap (gm.) and cresols (c.c.) in titre taken.	Vol. of water to give final clear soln. (if any).
100	169	261	clear soln.	5	100	clear soln.		
				5	75	clear soln.		
				5	50	cloudy		
				5	25	,,		
				5	10	,,		
				5	5	,,		
				5	3	,,		
				5	0	clear soln.		150–250
100	100	189	clear soln.	5	100	clear soln.		
				5	75	,,		
				5	50	,,		
				5	35	,,		
				5	25	cloudy		
				5	10	,,		
				5	7.5	,,		
				5	5	,,		
				5	3	,,	3 ; 1.34 ; 2.64	32.45
				5	1	,,	1 ; 1.34 ; 2.64	38.5
				5	0	clear soln.	0 ; 1.34 ; 2.64	26.90
200	100	287.5	clear soln.	10	100	clear soln.		
				10	50	,,		
				10	35	,,		
				10	25	,,		
				10	15	,,		
				10	10	,,	10 ; 3.5 ; 3.5	29.20
				10	7.5	,,	7.5 ; 3.5 ; 3.5	34.35
				10	5	,,	5 ; 3.5 ; 3.5	43.25
				10	3.52	,,	3.52 ; 3.5 ; 3.5	49.80
				10	1	,,	1 ; 3.5 ; 3.5	51.00
				10	0	,,	0 ; 3.5 ; 3.5	30.00
300	100	380	mucilaginous mixture made up to 1080 c.c. with 700 c.c. of paraffin and gives slightly cloudy liquid ; 25 c.c. of this taken as titre.	25	84	cloudy		
				25	59	,,		
				25	34	,,		
				25	19	,,		
				25	9	,,		
				25	0	,,		
400	100	475	a mucilaginous mixture; made up to 1875 c.c. with 1400 c.c. of paraffin ; still a mixture but now fluid ; 50 c.c. of this well-shaken mixture used as titre.	50	65	cloudy		
				50	40	,,		
				50	15	,,		
				50	0	,,		

TABLE B.

Ratio of soap (gm.) to cresols (c.c.) in initial mixtures.	GENERAL CHARACTER OF SOLUTIONS AND EMULSIONS FORMED ON DILUTION :
100 : 169	
100 : 100	mixtures with paraffin which give clear final solutions can be diluted to ½% paraffin and remain clear solutions ; slight turbidities due to ppn. of acid soap at extreme dilution. 5 c.c. mixt. to 5 c.c. paraffin—can be diluted up to ¼% paraffin and gives emulsion mixtures which are stable for weeks, showing no tendency to cream.
200 : 100	mixtures with paraffin which give clear final solutions can be diluted to ½% paraffin and remain clear except for deposition of a little acid soap. 10 c.c. mixt. to 15 c.c. paraffin—dilute up to ½% paraffin and get very stable emulsion mixtures.
300 : 100	emulsions on dilution show general tendency to commence to cream and clear in a day.
400 : 100	conc. emulsions stiff and lumpy and buttery. 50 c.c. of mixture alone (contg. abt. 35 c.c. paraffin) give stiff buttery emulsion at 250 c.c. ; slow addition of cresols causes a clear solution ; addition of excess cresols on shaking gives white emulsions, *i.e.*, cresols cause soap to dissolve more oil when added in correct amount.

Pickering's results show two interesting facts ; in the first place the more concentrated the soap *initially* present in his triturated solutions, the greater the amount of oil subsequently dissolved ; thus 100gm. of anhydrous soap was found to cause solution of more oil than 100gms. of anhydrous soap, say, at 50 per cent. concentration in water ; in the second place, the greater the amount of oil *initially* present before dilution, within certain limits, the greater the amount of oil in solution on dilution. The result from his table showing the greatest amount of paraffin oil dissolved was one in which he mixed 100 gm. of anhydrous soap diluted with 100 c.c. of water with 80 c.c. of lighting oil ; analysis on dilution showed 53.2 c.c. of the oil in solution. Ten c.c. of one of the mixtures (Table A., this paper), however, were capable of causing complete solution of at least 10 c.c. of paraffin oil in 30 c.c., or more, of water ; it so happened that the soap used in these experiments had 51.70 per cent. of anhydrous soap present (i.e., was approximately 50 per cent. concentration in water, as was Pickering's initially), so that 10 c.c. of the mixture contained about 3.5 gm. soap, 3.5 gm. water and 3.5 c.c. of cresols. It can be argued, therefore, that whereas 100 gm. of anhydrous soap in 100 gm. of water dissolve 53.2 c.c. of paraffin oil, 100 gm. of anhydrous soap in 100 gm. water, by the addition of 100 c.c. of cresols, are capable of dissolving about 287 c.c. of paraffin

oil (over five times as much). Regarding the anhydrous soap plus cresols as a cresols-soap, 100 gm. of this dissolve approximately 140 c.c. of paraffin. (Sp. gr. of cresylic acid = 1.05 approx.). So that the addition of cresols to soap makes oils much more soluble, weight for weight.

It should also be borne in mind that the amount of paraffin oil soluble in soap varies with the initial amount of oil in the mixture (*loc. cit.*) ; the results given here are only those which show *complete* solubility on diluting beyond a certain point. It is possible therefore that on mixing 10 c.c. of the cresols-soap with a large excess of paraffin (e.g. 100 c.c.) a much greater amount of the oil than 10 c.c. is dissolved ; this would only be apparent by a method of analysis such as Pickering's.

Detergent Action of Soaps.

Various experimenters, *e.g.*, Hillyer (5), have showed that reduction in the surface tension of water by addition of soap is an important factor in determining the detergent or cleansing action of the soap ; grease and oil on the skin or on fabrics are thereby emulsified, with a consequent loosening of "dirt" particles. Pickering (4) showed that the actual solubility of grease or oils in soaps probably determines the detergent action of soaps to a much greater extent than lowering of surface tension does ; for actual solution of grease and oils on the skin or on fabrics equally well facilitates the removal of "dirt" particles.

The addition of phenols such as cresols to soap has been shown to result in the formation of cresols-soaps, (liquid in the case of potash soaps), which show greatly increased solvent power for oils ; this, of course, means that the detergent action of such soaps is much greater. For this reason, it is legitimate to conclude that the commercial soaps containing phenols such as carbolic acid and cresols are, besides being antiseptic, much more efficient as detergent or cleansing agents, weight for weight, than ordinary soaps.

Use of Paraffin-Cresols-Soap Solutions as Sprays.

Pickering (4) makes no mention in his paper of the probable use of paraffin-soap solutions as spray fluids ; undoubtedly in most paraffin oil emulsions in soap media used in spraying, some of the oil will be present in solution.

Pickering (6) states that paraffin oil, diluted as a concentrated emulsion, is much more dangerous to trees than "naked" paraffin oil even ; moreover, emulsions of great concentration (50 per cent.) are needed before the killing power for insect eggs becomes comparable with that of naked paraffin. Even 1 per cent. emulsions are known to cause drastic scorch on foliage. In addition to the reasons given by Pickering, it is also probable that the creaming of emulsion mixtures, particularly when dilute, is largely responsible for harmful

effects (1). Now a solution of paraffin should remove Pickering's objection by reason of there being no protective pellicle of soap present to retard evaporation of the oil; it should obviate the ill-effects caused by creaming of emulsion mixtures, for a true (or stable colloidal) solution is homogeneous as regards distribution of molecules (or colloidal particles); it should also retain the killing power of naked paraffin, because of good contact powers (probably reasons for the lack of killing power shown by dilute emulsions are (1), the paraffin is dispersed in relatively large globules at relatively wide intervals and (2), the adsorbed layer on the globules prevents proper contact with the pest).

For the above reasons, paraffin-cresols-soap solutions may be recommended for trials as winter or cleansing washes. The best solution (largest amount of paraffin to smallest amount of cresols) would be one containing 100gms. of anhydrous soft soap, 100gms. of water and 100 c.c. of cresols to 287 c.c. of paraffin (see Table A.). This would make a concentrated solution, easily transportable by rail, containing 50 per cent. of paraffin oil and 17.5 per cent. of cresol by volume. The solution would dissolve easily on stirring into one-and-a-half times its volume of water to give a 20 per cent. solution of paraffin; moreover, dilution would not affect the solution, so that solutions of paraffin ranging from 0—20 per cent. could be made easily on the farm from the concentrated paraffin-cresols-soap solution.

One per cent. and ½ per cent. solutions of paraffin oil, prepared in this manner, might be advocated as foliage sprays instead of nicotine, so that "sucking" insects could be destroyed; it would be necessary, however, *to test these solutions thoroughly for prejudicial effects on foliage before recommending for general use.*

Tests were made by a colleague (Mr. Vyvyan), in his private garden, of a ½ per cent. solution of paraffin; the spray killed green fly on rose trees, without injuring the foliage; it killed cuckoo-spit insects and small snails, and made large snails very "uncomfortable" for a time. The time of spraying was during a rainy period (June, 1924).

The writer sprayed two apple trees infested with Woolly Aphis in a garden owned by a colleague (Mr. Adie), with a 1 per cent. solution, giving the trees a thorough drenching. Good wetting and spreading were obtained due to the soap present (7); the aphides were destroyed. One of the trees, a Cellini Pippin, was not scorched; the other (variety unknown to writer) showed about 2—4 per cent. of scorch (estimated by eye). The spraying was done on a hot sunny afternoon (August, 1924).

On holding a twig of the Cellini Pippin, infested with Woolly Aphis, in the solution, and withdrawing, the wool was seen to dissolve fairly rapidly; examination of the twig showed that the aphides had been killed practically instantaneously.

Later experiments, however, carried out on the tender shoots of rose trees in May (1925), showed the ½ per cent. solution to be ineffective against green fly, whilst the 1 per cent. solution scorched badly. The results were, therefore, directly contradictory to those of 1924, and it would appear that emulsions and solutions containing such oils as paraffin will be uncertain, and thus dangerous, for use as foliage sprays.

In conclusion it is necessary to thank R. H. Adie, Esq., M.A., for the use of his trees for trials ; M. C. Vyvyan, Esq., M.A., for trying the spray in his garden ; and D. Boyes, Esq., B.A., for acting as independent witness to some of the writer's trials.

Summary.

It is shown that paraffin oil is soluble in cresols-soap solutions to a much greater extent than in soap solutions ; hence it is argued that soaps containing phenols, such as commercial carbolic or cresol soap, should be much more effective as detergent agents than ordinary soaps.

The addition of cresols to paraffin oil emulsions in soap media stabilises the emulsion mixtures to creaming in many cases ; examples are given emphasising the fact that to form an emulsion the two phases need not necessarily be immiscible, but may be miscible to a large extent.

Solutions of paraffin oil at all concentrations up to 20 per cent. can be made by the aid of soap and cresols.

The solutions are suggested as winter washes for fruit trees ; a *tentative* suggestion is put forward that the more dilute solutions might be of use as contact insecticide foliage sprays, though, up to the present, contradictory results have been obtained.

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SULPHUR DIOXIDE AS A PRESERVATIVE FOR FRUIT.

By B. T. P. BARKER and O. GROVE.

Sulphur Dioxide (SO_2), the gas formed when sulphur burns in the air, possesses antiseptic properties which have been known and used for practical purposes almost from time immemorial. It has been utilised extensively for hundreds of years in the wine industry, especially for white wines, and nearly all the French white wines are treated with it at the present day. This is done partly to check fermentation and partly to prevent the development of micro-organisms causing disorder in the wines. For this purpose the dosage is generally applied in the form of gas produced by burning sulphur in the casks, or in solid form combined with a base, such as potassium meta-bisulphite and bisulphite of lime. Lately it has also been used in the liquid form, the gas being liquefied under pressure. This form is preferable, since it permits the use of exact amounts.

Its use as a preservative is frequent also in the case of other fermented or fermentable beverages, such as beer, cider and various non-alcoholic sweetened liquors. Custom has sanctioned the practice as legitimate and experience has proved that its effects on the human system are not positively harmful, provided that the dosage is not permitted to exceed certain limits of free sulphur dioxide.

Various articles of food can be preserved from decomposition by it. It has been found of particular service in the case of fruit and its use for fruit preservation forms the subject of this paper.

Its special value in this connection is its volatility. If, for example, fruit is preserved by immersion in a dilute aqueous solution of the gas, when required for consumption it can be freed from the preservative by the simple expedient of boiling, the gas being rapidly driven off at the temperature of boiling water.

In modern times it has played an important part in the jam-making industry as a preservative for fruit pulp. The latter article, while unsuited for the production of the highest class of preserves, is nevertheless a commodity of a distinctly useful order in particular cases for the manufacture of a cheap, wholesome jam, provided that it has been well preserved. It enables the manufacturer to handle a much larger quantity of fruit in glut seasons than he could otherwise do, since by converting into pulp the part of the crop which it is impossible for him to make up into jam during the fresh fruit season he can put it aside in store until pressure of work in the factory has slackened.

During the course of the war the present writers were closely concerned with the manufacture of a considerable quantity of fruit pulp and their experience with the produce, while illustrating its value from the different points of view of the fruit grower and the jam boiler, demonstrated also inherent difficulties in its preservation in satisfactory form. When large quantities are made, storage in wooden casks is adopted. Since these are not absolutely air-tight and sulphur dioxide is both volatile and readily oxidisable, the dose of preservative added as adequate in the first instance becomes in course of time reduced below the toxic limit for the reasons just stated. When that time is reached, if it is necessary to carry the fruit over a further period of storage a supplementary dose of the preservative must be added. Otherwise, as not infrequently has occurred, moulds, yeasts, and bacteria begin to invade the pulp and it becomes worthless. Thus by the time some pulps are used the total quantity of preservative added may be relatively considerable and, although little may remain in the pulp as such, there is an appreciable accumulation of free or combined sulphuric acid, resulting from the oxidation of the non-volatilised part of the sulphur dioxide.

For these reasons the writers turned their attention to the general question of the preservation of fruit by sulphur dioxide, with the object of discovering, if possible, an alternative method to pulping which should not be open to the objection of the use of a relatively large quantity of preservative. The method of preservation herein described is the outcome.

The objects of the experiments were to ascertain (*a*) the smallest possible dose of sulphur dioxide which must be added to fruit in the first instance to inhibit the development of moulds, yeasts and bacteria, (*b*) the conditions under which such preserved fruit should be stored to render, if possible, further addition of the preservative unnecessary, (*c*) the effect of the preservative on the fruit itself and (*d*) the possible uses other than jam-making to which fruit so preserved could be put.

A.—Dosage of Sulphur Dioxide required for Preservative Effect.

The earlier series of experiments were concerned primarily with this point. For obtaining accurate results it was clear that precautions were necessary in respect of possible diminution in the amount of sulphur dioxide actually available for preservative purposes by (*a*) evaporation, (*b*) oxidation and (*c*) combination with constituents of the fruit. The experiments were therefore made under the following conditions.

The fruit selected for trial, in all cases used as soon as possible after being picked and in perfectly sound condition, was packed in glass jars fitted with lids for hermetical sealing, such as are commonly utilised for fruit bottling. The preservative solutions to be tested were then simply poured over the fruit,

the latter being completely immersed and the jar filled with the solution so as to leave the least possible air space. The lid was then affixed securely to prevent access of air or escape of sulphur dioxide.

Strengths of the sulphur dioxide solution ranging from 0.02 per cent. to 2 per cent. were tried. In preparation of the solutions sulphur dioxide gas was led into cold water until the water contained 4—5 per cent. of the gas in solution. The exact strength was then determined by titration with a 0.1 normal solution of Iodine, and the stock solution diluted to the required degrees.

Experiments were carried out with the following fruits: apples, plums, raspberries, loganberries, black and red currants, blackberries, gooseberries, strawberries and oranges. With the exception of gooseberries and black and red currants completely satisfactory results were obtained with all solutions of appropriate strength. With plums especially, of which all the well-known varieties were tried, the results were excellent. In the case of black and red currants and gooseberries the fruits kept very well, but a certain hardening of the skins took place, which did not completely disappear when the fruit was stewed or converted into jam.

As regards strength of solution necessary to give satisfactory preservation, all strengths below .06 per cent. SO_2 were inadequate. Occasional instances in which solutions approaching that limit showed complete absence of development of any micro-organisms but the results were not sufficiently consistent. Strengths ranging from .06 to .08 per cent. have proved almost invariably satisfactory and from .08 per cent. upwards complete preservation has been invariably obtained in all the series of tests at Long Ashton.

At the Campden Research Station, where the method has since been tried on a semi-commercial scale, occasional failures with .08 per cent. solutions have been experienced in the case of raspberries. It is believed that these were attributable to no inadequacy in the preservative power of the solution at that strength, but to the packing of the fruit in the containers. The latter were large earthenware jars of 4—5 gallon capacity. Such a mass of soft fruit of the raspberry character tends to become compressed into a dense mass, to the interior of which it is not easy for the preservative solution to penetrate. Failure in such cases is not surprising unless, before the jars are sealed, particular care is taken to ensure proper mixing of fruit and solution. Another possible contributory cause may have been disproportion between the amount of fruit and the volume of preservative solution. On this point the following results of the Long Ashton trials have some bearing.

Analyses have shown that after storage of fruit in the preservative solution for some time in sealed air-tight jars the strength of sulphur dioxide in the solution is greatly reduced. This result is well illustrated by the accompanying analysis made of the contents of a jar of Monarch plums preserved

in a 0.08 per cent. solution of sulphur dioxide and examined after eight months.

TABLE I.

	Weight in grammes.	Per cent. Sulphur dioxide	
Plums	210.9	0.015	About one-fifth of original strength.
Liquid	267.1	0.014	
Whole sample ..	478.0	0.014	

Allowing for the quantity of sulphur dioxide absorbed by the plums represented in this table as uncombined SO_2, there is an actual loss of more than half the original amount added. This loss may be due either to oxidation to sulphuric acid or sulphates or to combination with constituents of the fruit. The available evidence deduced from other analyses suggests the latter as the main source of loss.

Hence the proportion of fruit to preservative solution in the container is of importance, since an unduly large amount of the former may lead to a reduction of sulphur dioxide strength below the preservative limit, with disastrous results on keeping quality.

Examination of the strength of the solution at various periods during storage has shown that the reduction in sulphur dioxide content is of a dual character. Within a few days after bottling there is a large loss, generally equal to about one-half the original amount added: after that time the rate of loss slows down rapidly and further reduction occurs very gradually. Presumably the initial rapid decline in strength of the solution is very largely to diffusion into the fruit, of which in most cases there is about the same weight in the bottle as that of the solution. The slower change later is probably representative of actual chemical changes.

In view of these results it would appear that, while it is necessary to use the preservative solution of a strength not less than 0.08 per cent. SO_2 to allow for absorption by the fruit, one of a concentration of 0.04 per cent. or thereabouts is actually sufficiently toxic to inhibit the growth of micro-organisms which may be placed in it. This figure is thus of significance in connection with the preservation of wines, cider and other beverages. It should not, however, be taken as infallible, since investigations at Long Ashton on this subject in connection with cider have shown that the toxic limit varies according to the conditions of nitrogenous nutrition of the organisms. It is interesting to find that this figure arrived at directly from the fruit bottling experiments is practically identical with the content of sulphur dioxide (free and combined) permitted by the French Government in wines.

B.—Conditions of Storage of Material preserved with Sulphur dioxide Solutions.

The foregoing work was, as already stated, carried out entirely in vessels from which air was absolutely excluded. Since fruit pulp is usually stored in bulk in wooden casks, which, as the cider work at Long Ashton has repeatedly proved, are far from air-tight, and since sulphur dioxide is both readily volatile and oxidisable, the results described may only be applicable for a relatively short time for pulp or fruit stored in this way in bulk. Recent trials at the Campden Research Station have shown that whole fruit stored in the wood in a 0.08 per cent. solution of sulphur dioxide keeps sound for an unexpectedly long time when the casks are securely bunged. On the other hand pulp behaves very irregularly.

The importance of using air-tight vessels was demonstrated in a few isolated instances in the preceding series of experiments, where the rubber rings used to make the air-tight seal for the glass jars became defective during the prolonged storage. In those cases micro-organisms began to develop in the jars even when the strength of the solution used was in the first instance well above the toxic limit.

Since the use of casks is so convenient for storage purposes, various methods of overcoming the difficulty of air access have been tried, none so far with complete success for pulp. Following out a suggestion that the presence of small amounts of a suitable chemical acting as an inhibitor for oxidation might slow down oxidation sufficiently to retain the sulphur dioxide in toxic amount, a number of substances unobjectionable from the food point of view were tested in this respect. These included glycerine, salt, various sugars, gum, lactic and tartaric acids, and alcohol. The appended tables give some of the results: in certain instances they show some evidence of slight inhibitory action.

TABLE II.

RATE OF LOSS OF SO_2 IN AQUEOUS SOLUTIONS IN PRESENCE OF SMALL AMOUNTS OF OTHER SUBSTANCES.

Series 1.

Treatment.	Substance added.	% content of SO_2 at end of test.
50 c.c. of 1 per cent. SO_2 solution, with addition of substances named. Kept in open bottles for 25 days at laboratory temperature.	Nil a.	0.0
	Nil b.	0.0
	Glycerine 1 drop	0.0128
	,, 2 drops	0.0320
	,, 10 ,,	0.0064
	,, 20 ,,	0.0128
	Salt 0.2%	0.0128
	,, 0.4%	0.0128
	Dextrose 0.4%	0.0256
	,, 1.0%	0.0256
	Gelatine 0.1%	0.0128

Series 2, 3, 4, 5 and 6.

Treatment.	Substance added.	Iodine Value.*	
		at start.	at finish.
Series 2.			
100 cc. of SO_2 solution (about 2.3% strength), kept in large closed bottle for 5 days and agitated in shaking apparatus daily for 1 hour.	Nil.	7·3	5·4
	Cane sugar 1%	7·4	5·6
	,, 2%	8·5	6·7
	,, 5%	7·2	5·2
	,, 10%	11·4	8·1
	,, 20%	8·6	5·9
	,, 50%	6·8	4·0
	,, 60%	7·0	3·0
Series 3.			
As in Series 2, except that strength of SO_2 solution used was approximately 1% and duration of test 3 days.	Nil	3·9	3·6
	Alcohol 3%	3·4	3·4
	Lactic Acid 1%	3·8	3·5
	Tartaric Acid 1%	3·8	3·6
	Gum 0.2%	3·3	3·1
	Dextrose 5%	3·7	3·4
Series 4.			
As in Series 2, but duration of test 10 days.	Nil a.	8.6	3·4†
	Nil b.	8.6	5·8
	Alcohol 1%	8.4	5·1
	,, 2%	8.3	5·7
	,, 4%	8.4	5·7
	,, 6%	8.1	5·4
Series 5.			
As in Series 2, but duration of test 4 days.	Nil	8.2	3·5
	Alcohol 1%	8.0	3·9
	,, 2%	8.0	4·3
	,, 3%	7·7	4·2
	,, 4%	7·7	4·3
Series 6.			
As in Series 2, with stronger SO_2 solution.	Nil	11.8	7·0
	Alcohol 3% + Cane Sugar 3%	11.2	7·3
	Alcohol 3% + Glycerine 1%	11.5	7·7
	Cane Sugar 2% + Glycerine 1%	11.4	7·4

† Stopper leaking.

* Expressed in number of c.c. of .1N Iodine solution used in titration of 1 c.c. SO_2 solution.

Nothing so far tried has been marked enough in its action to offer promise of practical significance, but the possibility of further advance along this line should be kept in mind.

The results in the above table for the control untreated solutions show the rapid loss of sulphur dioxide when air has free access to the liquid. It is clear, therefore, that the exclusion of air must be an essential point in any storage system utilised when this antiseptic is adopted as the preservative agent.

The substitution of another form of container in the place of wood for bulk storage has been considered. The objection in all cases so far examined which yield satisfactory storage is the relatively high cost of the storage vessel.

The ideal container for work on a large scale, but for its cost, would probably be the glass-lined cement tank used extensively in France for the storage of wine and cider. Casks well coated inside with paraffin wax or one of the special cask linings would serve the purpose, as long as they could be kept airtight.

Some experiments with small cement containers (cement one part, sand two parts, Pudlo 5 per cent.) covered with several layers of paraffin wax and mixtures of paraffin wax and resin have been made. With them there has invariably been a certain blackening of the fruit and the wax cover protecting the surface of the cement has been attacked in places.

C.—The Action of Sulphur Dioxide on Fruit.

Apart from the preservative action of sulphur dioxide by inhibiting the growth of micro-organisms, this substance has a definite effect on the fruit itself.

Its action on certain enzymes naturally present in the fruit was investigated some time ago by Miss Watson and Mrs. S. P. Wiltshire in the laboratory at Long Ashton. They found that the enzymatic activities of diastase, invertase and zymase were completely stopped in a 0.08 per cent. solution. It was concluded that the same would be the case when the fruit itself was kept in a similar solution. Subsequent experience in practice has proved this conclusion to be justified. Probably all enzymatic activity within the fruit is stopped and the enzymes themselves destroyed, the living cells of the fruit being killed at the same time. Mr. Appleyard, continuing work on this part of the subject at the Campden Research Station, has recently obtained direct evidence on this point, detailed particulars of which will be published later.

It has been found that fruit preserved in this way shows a progressive loss of "setting" or "gelling" power when made into jam, according to the length of time it has been stored in the solution. The suggestion has been made that this reduction of "gel" value is due to reduction of pectin content by its conversion to pectic acid or other derivatives by the action of the enzyme pectase. On that assumption this enzyme would need to be resistant to sulphur dioxide. The evidence available is against this view. Apart from the improbability of a particular enzyme remaining unaffected when all others are destroyed, there is no occasion to assume that the pectin change in this case is brought about by the enzyme. Pectin solutions depreciate regularly in "gel" value on long standing and fruit pulp, in which all the enzymes are destroyed by boiling, shows a similar deterioration. It is difficult to obtain satisfactory comparative figures, but there has been no clear evidence during the course of this work

to show that pectin loss is much more rapid in the one case than in the other. The writers' view is that in each instance the pectin change is a gradual hydrolysis taking place in an acid medium without the intervention of pectase and that the rate of change is determined by the composition of the system.

A noticeable change produced in the fruit by the preservative solution is a marked bleaching of the colour. The red colouring matters are those most affected. Red plums, strawberries, red currants and, to a rather less extent, raspberries and loganberries lose their red colour, being either completely bleached to white or retaining in various degrees a pink tint. The blue and purple colours are more resistant: thus black currants, blackberries, damsons and blue plums remain of a more natural appearance. Yellow and green pigments are little affected by the 0.08 per cent. solution. Greengages and yellow plums are accordingly not noticeably changed. The loss of colour, where it occurs, is temporary and persists only so long as sulphur dioxide is present. When the fruit is removed from the preservative solution and subjected to heat in jam-making or cooking, the sulphur dioxide is driven off and the original natural colour returns. A slight proportion is apparently permanently destroyed, since the final colour obtained after heating is rather less deep than the original: but so insignificant is the loss that the method has no drawbacks in its application on that account.

The remaining action of the preservative solution calling for mention in the toughening effect on the skins of gooseberries and currants to which reference has been made earlier in the paper. This is a definite disadvantage in the use of the method for these fruits and so far no means of overcoming it have been found.

D.—Applications of the Method.

The previous part of this paper has been concerned with the detailed description of a method by which fruit can be preserved whole for an indefinite time in a solution of sulphur dioxide of the lowest possible effective strength. So weak is it in fact that after treatment and without removal of the antiseptic the quantity of the latter present in the fruit itself is no greater than is permissive by French law in wines and ciders. When in addition there is taken into account the point that in heating the preserved material the sulphur dioxide is practically entirely driven off, it is evident that there is here a simple method of fruit preservation suitable for any purpose for which the fruit can be used after cooking, and free from any objection on the score of effect on the health of the consumer.

The original purpose in view at the start of the investigation was to arrive at a method of dealing with fruit pulp which would render the use of the latter in jam manufacture less open to objection than at present. In this matter the

interest of the fruit grower is considerable, for fruit pulping enables the jam industry to absorb more fruit in seasons of heavy crops and gluts than could be taken if the fruit could only be converted into jam while in the fresh condition. From a more general point of view also, a method which enables supplies of fruit to be put aside until required, in that way relieving congestion in the jam factory during the height of the fresh fruit season, must tend to the production of jam under better conditions and from sounder raw materials.

The main result of the work has been not so much to improve the position in respect of the fruit pulping method—although to a material extent this has been done by the information gained both on the conditions of storage required and the reduced quantity of preservative which can be made effective—as to provide an alternative method of preserving the fruit which possesses great advantages over the pulping method. The most important of these are (*a*) a great saving in time, the fresh fruit being packed direct into the storage vessel and then simply covered with the preservative solution and sealed down, (*b*) larger quantitives of fruit can be preserved during the fruit season, (*c*) no preliminary cooking or pulping, thus rendering unnecessary the provision of special pulping apparatus and equipment, (*d*) the fruit is preserved whole instead of being reduced to a state of pulp, enabling a more attractive grade of jam to be made, (*e*) less sulphur dioxide is required for preservation, (*f*) the costs of preservation are reduced very greatly by the elimination of the boiling and pulping process, (*g*) the preserved material keeps better, and (*h*) the quality of the jam made from the preserved material is much superior, being almost on a par with that of jam made from fresh fruit. Relating to the latter point, the following analysis of jam made from fruit preserved in this manner (Table III), is of interest in showing that the preservative is practically eliminated in the course of jam making. These figures were furnished by the sample of Monarch plums, other details concerning which have already been given in Table I.

TABLE III.

Composition after stewing.	*Grammes. Weight in.*	*Per cent. Sulphur dioxide.*
Plums	102.8	0.007
Liquid	54.5	0.004
Whole sample	157.5	0.006
Composition of jam	—	0.003

The method is therefore put forward not as a substitute for pulping in the jam industry but as one to supersede it by virtue of its superiority in almost every respect. It is in addition equally applicable to jam making on a smaller scale and under domestic conditions. While normally in the latter case the stock

of jam is made during the course of the fruit season from fresh fruit, there are occasions, particularly where persons use their own home-grown fruit, when it is a distinct advantage to be able to put aside a supply of fruit to await conversion into jam until a convenient opportunity.

Fruit thus preserved serves a valuable purpose outside jam making. It can be brought into use in all respects in place of canned or bottled fruit. For the past four years the writers have tested it under domestic conditions as stewed fruit and for pies and puddings and have found it as good as fruit bottled and sterilised in the ordinary way. If anything, the fruit is rather better, although for red fruits the colour is sometimes slightly less. It is necessary to observe reasonable precaution, when used in the home. It is unfit for consumption until it has been cooked: but, since all the uses proposed involve cooking in any case, this does not involve any additional operation. Generally by the time the fruit is cooked the sulphur dioxide has been completely carried off in the steam. Before finishing off the stewing it is, however, advisable for those unacquainted with the method to taste the fruit to ascertain if any flavour of the preservative remains. This flavour is so pronounced and familiar to all that very small amounts can be readily detected in this way. If any taste is noticeable, the cooking should be continued for a slightly longer time till nothing can be detected. The fruit may then be assumed to be in fit condition for consumption. When used in tarts and puddings this procedure is not possible. As a precautionary measure in these cases the fruit may be stewed for a short time and kept at the boil for a few moments before being placed in the tart or pudding, the latter being cooked in the usual manner. This precooking is not generally necessary, but is a simple means of ensuring satisfactory results.

For home use this method of preserving is proposed as a substitute for bottling on account of its simplicity and the saving of time and trouble. The bottling method is equally good as regards quality of product and is absolutely safe in the sense that there is no risk of preservative being taken into the system of the consumer: in other respects the advantage rests with the sulphur dioxide method.

There are other possibilities with regard to details of method of treatment, handling of the produce and mode of use which offer promise of increasing the utility of this form of preservation. Investigations on these are now in progress at the Campden Research Station.

E.—Details of Method for General Use.

While the details of the method have been indicated earlier in the paper in connection with the experimental work, the particulars advised for general use should be somewhat amplified.

Fresh gathered fruit is sound condition should be selected for preservation. The preservative fluid should be an aqueous solution of sulphur dioxide of a strength not less than 0.08 per cent., nor more than 0.1 per cent. SO_2. The fruit should be prepared as for bottling. It should then be placed in the storage vessel, the latter being well filled with the fruit and care being exercised that packing in a solid mass does not occur. In the case of soft, easily compressible fruit, such as raspberries, which easily aggregate into a solid mass, a small quantity of the solution should be placed first in the receptacle and the latter agitated at intervals during the packing, further liquid being added as the vessel is filled up. This will ensure thorough mixing of the fruit and preservative. When sufficient fruit has been added, the vessel should be filled as completely as possible with the solution, to cover the fruit entirely and leave the smallest possible air-space above. The vessel should then be sealed down. It is important to see that the seal is airtight. Provided these operations are properly carried out, no further attention should be required until the fruit is wanted for use. The vessel is then unsealed and the fruit removed. The liquor in the vessel may, if desired, be used with the fruit at discretion. It contains appreciable quantities of flavouring substances diffused from the fruit. Its use, however, should be accompanied by rather longer cooking than when the fruit is used without it, for there is more of the preservative to be driven off. When the fruit is to be used without it, the liquor should be drained off and the fruit itself may be rinsed with water to remove any adherent liquor.

As regards the type of storage vessel, for small scale work fruit bottles and earthenware jars are satisfactory. For methods of sealing these and for details of suitable receptacles for larger scale work enquiries should be made from the Resident Director, Research Station for Fruit and Vegetable Preservation, Chipping Campden, Glos. Supplies of the preservative solution of standard strength can also be procured from that Institution.

In conclusion, it may be stated that the recent Departmental Committee on Preservatives appointed by the Ministry of Health have had this method of preserving fruit under consideration and in their recently issued Report have recommended that sulphur dioxide within limits which somewhat exceed those required in this connection should be permissible for fruit preservation. It may therefore be accepted that the use of this preservative in the manner here indicated is regarded as legitimate and not detrimental to health. The publication of the details of this work has been deferred for some time so that the recommendations of that committee might be available for reference.

SILVER-LEAF DISEASE.—V.

By F. T. BROOKS and W. C. MOORE.

I.—INTRODUCTION.

Towards the end of 1922 additional facilities for the continued investigation of Silver-leaf Disease of Fruit Trees were provided by the Development Commission through the Ministry of Agriculture and Fisheries, which have enabled these researches to be prosecuted on a larger scale than hitherto. The increased facilities include a small experimental plantation of plums, kindly loaned for a period of years by Mr. A. R. Fordham, and the provision of a greenhouse suitable for growing plum trees in pots. Certain investigations have also been carried out at the East Malling Research Station and the John Innes Horticultural Institution, by kind permission of Mr. R. G. Hatton and Mr. W. Bateson respectively. Valuable information has been given us from time to time by officials of the Ministry of Agriculture and Fisheries, especially Dr. G. H. Pethybridge, and by others, notably Miss A. D. Mackenzie.

The larger numbers of trees now available for experimental purposes have enabled the researches during the past two or three years to be concentrated chiefly upon the following issues : (1) Can *Stereum purpureum* infect wounds in fruit trees in all months of the year with equal facility ? (2) Does this fungus infect new exposures more readily than wounds of long standing ? (3) What are the best substances for the protection of wounds against this fungus ? These problems are intimately connected, and it is obvious that the right solution of them will have a marked influence upon views as to the time and manner in which operations involving the cutting out of branches of fruit trees should be carried out. The bearing of these problems upon the incidence of Silver-leaf disease is manifest. The sequel will show that considerable progress has been made in the solution of these problems.

Silver-leaf disease is present to a greater or less extent in all the chief plum and apple growing districts of the world. Cunningham (11) has called attention to its prevalence in New Zealand, and Putterill (19) to its existence in South Africa. Güssow (15) reported its occurrence in Canada in 1912, and more recently Heald and Boyle (16) have called attention to the menace of this disease in the important apple-growing districts in the State of Washington. The symptoms and course of the disease in all these countries are essentially the same as in England. It is now universally admitted that the primary cause of the Silver-leaf disease which is associated with the dying back of fruit trees, is the fungus *Stereum purpureum*.

It is not proposed to give a list of new hosts for this disease which have come under our observation during the last three years, Many shrubby plants have

been seen to be affected by this disease, in which it has not hitherto been recorded. Cotton (10) has recently called attention to the killing of Rhododendrons by *S. purpureum*. In paper IV. of this series Silver-leaf disease in roses was recorded for the first time. Since then other varieties of roses, notably ramblers, have been occasionally seen to be affected by this disease, with the consequent death of the stems and development of *S. purpureum* thereon. A few additional cases of the disease in pears in this country have been observed, but the disease is still extremely rare on this host. In this connection it may be mentioned that Dr. J. Westerdijk informs us that it is easy to produce silvering symptoms in certain varieties of pears in Holland by inoculation with the fungus ; all the inoculations of pear trees which we have made in this country have failed to reproduce the disease.

An indication of the relative suceptibility and resistance of the chief commercial varieties of plums and apples was given in the previous paper of this series. It may now be added that in our experience the comparatively new variety of plum, Purple Egg, is resistant to this disease.

In the previous paper of this series (3) a list of plum stocks was given which had been shown to be affected by the disease upon artificial inoculation with the fungus. It was pointed out that Myrobolan B was the most resistant of those tested : this has been confirmed by another series of experiments. Other stocks which have been shown to be moderately susceptible to the fungus by artificial inoculation (as described in the previous paper) are Mariana, Cluster Damson, St. Julien B, Kroosjespruim, Black Damas C, Myrobolan A, C and D, Bastard Common Mussel, and St. Julien G (Toulouse). Although all these stocks can be artificially infected with Silver-leaf disease, the percentage of recovery amongst them is high, and there is no doubt that all the plum stocks in common use are much more resistant to the disease than varieties of plums such as Victoria and Czar. It is, of course, a matter of common observation that long after the upper part of the tree has been killed by the disease, the stock frequently remains alive and throws up suckers. As pointed out in the previous paper, the influence of the stock on susceptibility of the cultivated variety to the disease is probably indirect ; data are gradually being accumulated in regard to this, but it will obviously be a long time before a confident statement can be made.

In previous papers on this disease (1, 2, 3) attention has been called by one of us to examples of silvered foliage, showing the histological symptoms of the disease caused by *Stereum purpureum*, which was not caused by this or any other fungus, but by a general physiological disturbance, and also examples of silvered foliage in which the "silvering" was due to innumerable punctures of the epidermis by insects. Many similar instances of the first kind have been seen during the last two years, especially in seedling plants and in the

leaves of certain herbaceous plants at the end of the winter. "Silvering" of this kind, however, never has a serious effect upon the plants, and is a comparatively temporary phenomenon. Our present outlook upon these cases of "silvering" is the same as that recorded in previous papers of this series. As regards "silvering" which is not due to attack by *Stereum purpureum* Petri (18)* and Ciferri (8)* have recently made some interesting observations to which brief reference must be made. Petri (18) records the case of a peach tree which threw up silvered shoots after being cut back, in which the appearance of "silvering" was due to an abnormal accumulation of crystals of calcium oxalate in the upper epidermis. He also states that "silvering" in *Viburnum tinus* is sometimes due to the separation of the cuticle from the rest of the outer wall of the epidermal cells. Ciferri (8) records "silvering" in peaches and plums which had been cut back. According to his investigations this was due to the detachment of the cuticle. Both authors agree, however, that the silvering of foliage which is associated with the dying back of branches is entirely due to *Stereum purpureum*.

II. INFECTION EXPERIMENTS WITH SPORES OF *STEREUM PURPUREUM*.

(1) INFECTION OF CUT PLUM TWIGS IN THE LABORATORY.

In "Silver-leaf Disease, IV." (3) it was pointed out that plum twigs could be readily infected in the laboratory with *Stereum purpureum* by placing a spore emulsion on the cut extremities, the other ends of the twigs being kept in water during the experiment. It is now known why it is unnecessary to keep the inoculated extremities of such twigs under moist conditions as we (4) have shown that the spore emulsion is sucked a considerable distance into the vessels, so that the spores and young germ tubes are protected from desiccation during the critical stages of the initiation of infection.

For the last two years experiments of the same kind have been carried out, month by month, to ascertain if infection of cut plum twigs, three to four years old, can be brought about at all times of the year, and to compare the speed of invasion in different months. Both Czar and Victoria twigs have been used in these monthly experiments, but there is no material difference in the reaction to invasion on the part of these varieties, so that the results may be presented together. Uninoculated twigs were always kept as a control, and with the exception of a very small number which became infected with extraneous micro-organisms, these remained healthy until the end of the experiment, showing only a very slight amount of discoloured tissue below the exposed surface.

* We are much indebted to Mr. A. W. Exell of the British Museum (Natural History) for translations of these papers.

From March to August inclusive, infection of these twigs has proceeded rapidly so that in the course of six weeks the fungus has invaded them on an average to a distance varying from four to seven inches. This has been determined both by tracing the discolouration of the wood caused by the fungus and by the examination of sections. Inoculation of cut plum twigs, 9 inches long, in May often resulted in complete permeation by the fungus within six weeks, accompanied by the development of fructifications of *S. purpureum* at about the level of the water in which the twigs stood. From September to February inclusive the rate of penetration has been much less. In September the average invasion was 1 inch, in October $\frac{1}{2}$ inch, and in November $\frac{1}{5}$ inch. The results for December and January are somewhat aberrant, and differ for the two years over which the experiments have extended. In December, 1923, the penetration was 4 inches, but in 1924 it was only $\frac{1}{2}$ inch. In January, 1923, the penetration was $\frac{1}{2}$ inch, and in 1924, $3\frac{1}{2}$ inches, the result in 1924 being comparable with that of December, 1923, i.e., the previous month. In February, 1923, invasion occurred to a distance of 6 inches, and in 1924 to 2 inches. It is clear from these results that, although the initiation of invasion of cut twigs can take place throughout the year, the rate of penetration is much more rapid at one period than another. The difference in rate of invasion during the two periods cannot be wholly due to changes of temperature, for fluctuations of this kind in the laboratory are small. The divergence is probably chiefly caused by physiological differences in the twigs. Although the periods of rapid and slow penetration have been approximately constant during the two years, there is some fluctuation in the rate of invasion during December, January and February. This fluctuation is also probably due to variability in the physiological state of the twigs in the two seasons, for the laboratory conditions of experimentation were as constant as could be arranged.

(2) Infection of cut Laburnum Twigs in the Laboratory.

As is well-known, heart wood becomes clearly differentiated from sap wood at an early stage in the laburnum, the heart wood being brownish-black in colour in contrast to the almost white sap wood. It was thought, therefore, to be of interest to inoculate the cut ends of laburnum twigs with a spore emulsion of *Stereum purpureum* to ascertain if there was any difference in the rate of invasion of heart wood and sap wood respectively. Attention has been previously called in this series of papers to the frequent destruction of laburnum trees by the fungus.

Freshly-cut twigs of laburnum, about ten years old, were placed in water in the laboratory in June, and the newly exposed extremities were covered with a spore emulsion of *Stereum purpureum*. At the same time control twigs were left uninoculated. After six weeks the inoculated twigs showed a marked

difference between the heart wood and the sap wood, the former being covered with *Penicillium* and the latter with rudimentary fructifications of *Stereum purpureum*. Both the heart wood and the sap wood of the control twigs were covered with *Penicillium*. Upon cutting up the inoculated twigs it was found that the sap wood was permeated with the mycelium of *Stereum purpureum* causing the usual brown discolouration, whereas the fungus had not entered the heart wood, it being replaced by a purely superficial growth of *Penicillium*. The growth of *Penicillium* both on the heart wood of the inoculated twigs and over the whole surface of the control twigs was doubtless due to these being kept in a moist atmosphere. Ordinarily, *Penicillium* does not grow upon woody tissues exposed to a dry atmosphere. Attention has previously been called (3) to the fact that *Stereum purpureum* is a fungus which preferably invades woody tissues that contain living cells. The contrast in its behaviour towards the heart wood and sap wood of laburnum is additional confirmation of this view.

(3) INFECTION OF EXPOSED EXTREMITIES OF PLUM BRANCHES IN NATURE.

(*a*) *Inoculations made almost immediately after exposure.*

While experiments on the infection of plum twigs in the laboratory were being carried out, similar experiments were made, month by month, in the field.

For this purpose two to three-year-old twigs of Czar plums were cut back and an emulsion of freshly-deposited spores of *Stereum purpureum* was applied two days and four days afterwards. The object of giving two applications of spores was to ensure ample opportunity for infection. About twenty wounds were inoculated each month, of which three or four were cut up after three months and the same number after six months in order to determine by microscopic examination whether infection had occurred. The remainder were left on the tree to see whether they resulted in silvering of the foliage in the immediate neighbourhood of the inoculation. If silvering developed within a reasonable period of time, this also was taken as a sign of positive infection. In the case of the March and April inoculations silvering of the foliage often appeared before some of the twigs were due to be cut up.

The results of two years' inoculations are given in the following table :

	Positive infections. (1923-4)	(1924-5).
April	100%	100%
May	71%	25%
June	0%	0%
July	6%	0%
August	0%	36%
September	—	30%
October	100%	64%
November	21%	50%
December	77%	86%
January	100%	—
February	75%	100%
March	94%	14%

No inoculations were carried out during September, 1923, and January, 1925.

These results indicate that there are striking differences in the chances of infection by *Stereum purpureum* in nature at different times of the year. The most noteworthy feature of these data is the almost complete absence of infection during June and July, and in one year in August, whereas in other months infection takes place sometimes to the extent of 100 per cent. of the inoculations. Exact agreement in the relative amount of infection is the corresponding months of succeeding years is not to be expected because of variations in the weather and other factors, but the results as a whole agree sufficiently to be significant. Slight fluctuations in the periods of maximum and minimum infections from year to year are not surprising.

Most of the twigs inoculated during June, July and August, which did not become infected, were cut up after a suitable interval in order to ascertain the cause of the inhibition of complete infection. Examination showed that the fungus spores had germinated and that the mycelium had penetrated to a distance of about half an inch, but further progress of the fungus had then stopped. The wood permeated by the mycelium was brown in colour as usual owing to the presence of gum in the cells, but, on the margin of the wood affected in this way, there was a narrow zone much more intensely discoloured, and, in fact, almost black. The vessels in this deeply discoloured zone contained even more gum than the region permeated by the mycelium, and the gum was darker in colour than in the latter. The mycelium had not entered this delimiting zone, so that the fungus was completely shut off from the healthy wood beyond. It seems certain that this "gum barrier," as it may be called, definitely prevents the fungus from proceeding further. Thus the lack of infection leading to Silver-leaf disease is not due to failure of initial invasion, but to a pronounced reaction on the part of the host leading to the formation of an impenetrable barrier of gum-like substances. In Silver-leaf disease IV (3) attention was called to the presence of a similar "gum barrier" in Pershore plum trees which had recovered from the disease, and also in pear trees which had been unsuccessfully inoculated with the mycelium of the fungus. It seems therefore that the formation of gum of this kind in the host tissues is generally the cause both of lack of infection and of recovery from infection by this fungus. For reasons which have already been given in the fourth paper of this series it is suggested that the protective gum in the almost blackened zones may be different from the gum of the brown discoloured wood permeated by the mycelium; it also fills the elements of the wood more completely than does the ordinary type of gum. On the other hand, the deepening of the colour in the "barrier" may be due chiefly to gum being present in greater quantity.

Another proof that protective "gum-barriers" are formed with particular facility during the summer is afforded by the results of a series of experiments in which plum trees in pots in a greenhouse were inoculated during June, 1924 with mycelium of the fungus. Of forty trees inoculated in this way only two ultimately became silvered. Several of the inoculated trees which failed to become silvered were cut up in August, 1925, when it was found that in each of these trees the progress of the fungus had been quickly stopped by the formation of a "gum-barrier." Consequently the trees did not become affected by silver-leaf disease. In previous papers of this series it has been pointed out that it is extremely difficult to bring about successful infection of plum trees by mycelial inoculations during the summer. The reason for this is now apparent in the light of the results just recorded: in all such cases it is the ready formation of a "gum-barrier" which prevents successful invasion.

The reasons for the rapid formation of a "gum-barrier" in June, July and August, thereby preventing infection, are by no means clear. "Gum barriers" are certainly not limited in time of formation to these months, because whenever there is failure to proceed with invasion after initial penetration, and in all cases of recovery from the disease, a "gum-barrier" is responsible for the defeat of the fungus. There is reason to suppose, however, that "gum barriers" are more readily formed in the summer months than at other times of the year. This is probably due to some special physiological condition of the twigs during these months.* Alternatively, these barriers may be the more readily formed then because the fungus perhaps attacks most vigorously during that period. With the enhanced temperatures of the summer the fungus grows faster, although it may be argued that with higher temperatures the protective gum is also more easily formed. If it be true that the protective gum barriers are brought into being by the vigor of attack of the fungus, the ultimate escape from infection can be compared with the well-known case of resistance of certain varieties of wheat to *Puccinia glumarum*, where the ultimate immunity is due to a too vigorous initial attack by the fungus. The almost constant lack of infection during the summer months is, however, probably related to some peculiar feature in the initiation of attack of the fungus during that period, in association with the wound response of the host; otherwise one would expect that invasions by this fungus begun in April would stop in June: that is certainly not the case. It is the early stoppage of invasion in the summer months which is of peculiar interest in these experiments, but whether this is due primarily to the host, or to the fungus, or whether the "honours" are even between the two, for the present remains somewhat

* By the kindness of Mr. T. Swarbrick we have been able to read an account, before publication, of work by him on the blocking of wounds in trees through gum formation. Mr. Swarbrick also finds that the blocking of woody exposures by gum takes place more readily in the summer months than at any other time of the year.

obscure, although the available evidence points to the physiological condition of the host as being most important.

The rate of penetration of plum twigs successfully inoculated with spores of *Stereum purpureum* varies of course at different times of the year; it is doubtless dependant partly upon the temperature and partly upon the concentration of food material available for the fungus in the wood. Invasion during January and December is naturally slow at first but proceeds rapidly as the temperature rises. Dixon and Atkins (13) have shown that there are always some soluble carbohydrates as well as mineral salts present in the tracheæ of deciduous trees, so that food material is available for the fungus throughout the year, altogether apart from the ability of the fungus to secrete enzymes which transform starch and other complex substances. According to the researches of Dixon and Atkins (13) the maximum concentration of soluble carbohydrates in the tracheæ occurs in April, after which there is a considerable fall until a minimum is reached in September. It is of interest that in April, 100 per cent. of the inoculations were successful and that the period of diminishing soluble carbohydrates coincides roughly with the period during which it is almost impossible to bring about natural infection by spores.

There are some striking differences between the results of the laboratory and the field inoculations of plum twigs. Conclusions drawn from the former as to the possibilities of infection in nature would obviously be erroneous. The experiments show that in nature it is almost impossible to bring about infection of fresh exposures during June, July and August, while cut twigs kept in the laboratory are readily infected during these months. There are important differences in physiological state between cut twigs attached to trees, and the divergence in infection is doubtless bound up with these differences.

The results of these inoculation experiments carried out in nature at different times of the year have an important bearing upon the time of cutting out dead wood in silvered fruit trees. By the Silver-leaf Order of 1923, the Ministry of Agriculture insists upon fruit-growers cutting out all dead wood in fruit trees liable to harbour *S. purpureum* before July 15th each year. This date was originally suggested because fresh fructifications of the fungus giving spores are least abundant during the early part of the summer, and it was thought that, if healthy wood were exposed in this process of cutting-out, re-infection would then be least likely to occur. It is also easier to cut out dead wood in fruit trees during the early summer than in the winter, because at the former time there is the clearest differentiation between healthy and dead branches. The results of the above inoculation experiments also demonstrate that it is best to cut out the dead wood in fruit trees in the weeks immediately preceding July 15th, because of the extreme unlikeliness that spores of *S. purpureum* will cause infection during June and July, even if spores of the fungus are then present in

the air. On the other hand, to cut out dead wood in March and April is to court disaster, because in the latter month infection is brought about with great readiness.

(*b*) *Inoculation made after varying periods of exposure.*

In "Silver-leaf Disease, IV." (3) it was suggested that *Stereum purpureum* probably infects newly exposed wood more readily than wood which has been exposed for some time. During the last two years experiments have been carried out to test the truth of this statement. At four different periods in the year plum branches in nature were cut back and subsequently inoculated with a spore emulsion of *Stereum purpureum*, one week, one month, three months, and six months respectively after exposure. On each occasion three branches were treated identically. The following are the results of one of these experiments :

Month of Cutting.	Period of exposure before inoculation.	Number of positive infections out of three inoculations.
January, 1923.	1 week.	3
	1 month.	1
	3 months.	0
	6 months.	0
April, 1923.	1 week.	2
	1 month.	1
	3 months.	0
	6 months.	0
July, 1923.	1 week.	0
	1 month.	0
	3 months.	0
	6 months.	0
October, 1923.	1 week.	0
	1 month.	0
	3 months.	0
	6 months.	0

This table must be interpreted in the light of the results obtained by inoculating plum branches in the field at different times of the year immediately after exposure. Owing to the general absence of infection in July one would scarcely expect infection to take place in the above series of experiments when branches were inoculated three months after exposure in April and six months after exposure in January. Nor on the same basis would one expect infection to occur one week and one month respectively after exposure in July. Otherwise the results confirm the view that *Stereum purpureum* infects woody tissues much more readily at or immediately after exposure than at a later period. Another

series of experiments gave essentially the same results. With regard to the absence of infection after one week's exposure in October, it will be seen from the first table that infection readily occurred during this month when spores were applied almost immediately after the wounds were made.

Woody tissues soon after exposure inevitably become invaded with a variety of micro-organisms, the germs of which are constantly present in the air, so that after an interval of three months there may be a considerable number of invading organisms, which, except in the winter months, will have caused an appreciable amount of discolouration below the exposed surface. It seems clear that a fungus like *Stereum purpureum* with parasitic proclivities cannot pass through tissues occupied by other micro-organisms as easily as through sound tissues. Some of these twigs which did not become infected after exposures of three or six months before inoculation, have been cut up after the lapse of another three months ; for a distance of half an inch to an inch on an average below the surface discoloured tissues are invariably found, which are bounded by a darkly discoloured "gum barrier" similar to that which is characteristic of failure of infection by *Stereum purpureum.* Sections through the invaded tissues frequently showed the characteristic mycelium of *S. purpureum* ; the spores used for inoculation had evidently germinated and had permeated to come extent tissues already invaded by other fungi. The *Stereum* hyphæ could not often be found as far as the special "gum barrier," although other mycelia could be so traced, so it remains uncertain whether the barrier was primarily caused by other invading organisms or by *Stereum purpureum* working in association with them. Invasion of woody tissues by other micro-organisms often leads to the formation of protective "gum barriers," as e.g., after wounds have been left naturally exposed for periods of three to nine months. As stated in "Silver-leaf Disease, IV." (3) there is great diversity of species among the micro-organisms which invade woody tissues to a limited extent, but without acting as dangerous parasites.

(4) Other Infection Experiments.

The results of the main series of inoculation experiments with the spores of *S. purpureum* indicate clearly that the longer the wound has been exposed the more difficult is it for this fungus to infect. After a month's exposure *S. purpureum* rarely infects woody tissues, and no successful invasion by this fungus has been seen where the wood has been exposed as long as three months. It has been shown that with all wounds exposed for a considerable period the extremities become invaded by a variety of micro-organisms. If, for instance, the spores of *S. purpureum* be placed on wood exposed for about a month, invasion by other fungi will have already begun. These other fungi have already altered the nutritive conditions of the wood and they are already established as

competitors with *S. purpureum* when the latter begins to develop. In the majority of cases *S. purpureum* fails to penetrate completely the tissues already occupied by other fungi, and therefore disease does not ensue. In such exposures the spores of *S. purpureum* germinate under moist conditions, but the germ tubes make slower progress than in fresh tissues and soon cease to develop further.

As woody tissues exposed to the air are usually invaded by a considerable mixture of micro-organisms, it was thought desirable to ascertain whether *S. purpureum* could cause invasion through tissues already attacked by specific fungi. For this purpose *Sclerotinia cinerea* and *Diaporthe perniciosa* were chosen as being two of the commonest pathogenic fungi on plum trees.

Cankers of plum branches caused by *Sclerotinia cinerea* were inoculated, both in the field and in the laboratory, with spores of *Stereum purpureum* at a time of the year favourable for infection. None of the cankers in the field experiment were successfully traversed by *S. purpureum*, and only one of those inoculated in the laboratory succumbed to infection, as shown by the fungus *S. purpureum* passing far beyond the limits of the canker. Little emphasis, however, can be laid upon this single success as experience has demonstrated that experiments on cut twigs cannot be used as an accurate guide to behaviour in the field.

In another experiment small plum branches in the experimental plantation were cut back and immediately inoculated with a spore emulsion of *Sclerotinia cinerea*. A month later most of these twigs were inoculated with a spore emulsion of *Stereum purpureum*. A few were cut up to determine the progress made by the *Sclerotinia*, which was only slight. On cutting up the twigs after the lapse of six months it was seen that *S. purpureum* had in no case caused infection.

As far as these experiments go, it seems safe to conclude that under field conditions *Stereum purpureum* does not infect plum trees through tissues already killed by *Sclerotina cinerea*. This conclusion agrees with field observations over many years that plum trees seriously affected by *Sclerotinia cinerea* (Brown Rot) are not more susceptible to Silver-leaf disease than are healthy trees.

With *Diaporthe perniciosa* laboratory experiments only are complete so far, but these also indicate that *Stereum purpureum* is rarely, if ever, able to pass completely through tissues already permeated by the first-named fungus. A considerable field experiment of the same kind is in progress, but the results are not yet available.

In view also of successful infection through leaf-scars (21) and lenticels by other wound parasites attempts have been made to induce infection through these structures by the spores of *S. purpureum*, but entirely without success.

III. WOUND PROTECTION IN FRUIT TREES.

The investigations outlined in "Silver-leaf Disease, IV." (3) on the subject of wound protection in fruit trees have been continued on a large scale during the last two years. In view of the fact that *Stereum purpureum* infects wounds most readily immediately after exposure all the experiments have been carried out on the basis of placing the protective over the wounds directly after these were made. The type of wound generally used for these experiments has been that made by a pruning knife or secateurs in severing branches, but wounds obtained by splitting asunder two branches at a fork have sometimes been employed. Branches two to three years of age have been mostly used for these wound experiments, which have been carried out on plum trees (chiefly Czars) in the experimental plantation. With the more important substances tests have been carried out practically during every month in the year.

Throughout these experiments an emulsion of spores of *Stereum purpureum* has been placed on the protective substance a few days after the latter has been applied, or after a longer interval. The spore emulsion was always added in dry weather, and sometimes more than one application of spores was given. The branches thus treated were generally left in order to see if silvering developed in connection with them, although at certain times of the year they were cut up to determine whether infection had occurred, without waiting until the foliage appeared.

Many different protectives have been used in these experiments, but only the more important of these will be discussed in detail. An important consideration with these protectives is that, for use by fruit-growers, they should be practically harmless to the bark. One of the best of these protectives has had to be discarded because of its toxicity to the tissues.

Antifouling Paint. As pointed out in the previous paper of this series, this paint, which is used on ships' bottoms, gives a splendid surface on drying and does not readily crack, although it is somewhat toxic to the bark. Apart from the latter defect it seems an ideal means of protecting wounds from invasion by *Stereum purpureum* as, notwithstanding innumerable attempts to infect wounds covered by it with this fungus, not a single positive infection has been recorded. Upon request, the manufacturers have made this paint thicker and have reduced considerably its toxicity without altering its advantageous characters, but unfortunately it is still too toxic to the young bark of fruit trees, and therefore cannot be generally recommended for use by fruit growers. The bark of young branches is sometimes killed for two to three inches below the paint. With older bark the toxic influence of the modified antifouling paint is appreciably less, and for covering large wounds in old trees, whether fruit trees or timber trees, its toxicity to the tissues can be ignored.

Red Oxide Paint (*as sold*). In view of the considerable toxicity of antifouling paint to young tissues other ready-made paints have been used as wound protectives. Red oxide paint (as sold) gives a poorer " surface " than antifouling paint and takes a long time to harden ; moreover, it has a tendency to run down the bark as it is too liquid. The latter defect could, however, be remedied by allowing the paint to thicken before use. This paint (as sold) is less toxic to young bark than is the modified antifouling paint. Below wounds about half an inch in diameter the bark is killed to a maximum of a quarter to half an inch after six months, usually only on that side of the twig towards which the cut slopes and away from the side bearing an attached shoot. This paint is, however, useless for protection against *Stereum purpureum*. In one series of experiments in which a spore emulsion was placed on wounds covered with the paint within a few days of the application of the latter, all of the ten shoots so covered became infected with the fungus.

White Lead Paint (*as sold*). Ready-made white lead paint gives a better " surface " on wounds in plum trees than does red oxide paint, and it hardens more rapidly than the latter. It shows less tendency to run down the bark than does red oxide paint. It is somewhat less toxic to young bark than red oxide paint, and, when used to cover wounds about half an inch in diameter, the maximum distance to which its toxic influence has extended after six months is one-quarter of an inch, usually only on that side of the twig towards which the cut slopes away from the attached shoot. This paint also is of little use as a protection against *S. purpureum*. In one experiment, eight out of ten wounds covered with the paint and inoculated with a spore emulsion within a few days became infected with the fungus.

Home-made Paints. In view of the difficulties encountered with paints as sold ready for use paints have been made up as follws :

(*a*) *Red Oxide Paint*. To 2 lbs. of red oxide in linseed oil (as bought) add two teaspoonfuls of paste driers and about a tablespoonful of linseed oil. Mix. Then add turpentine gradually and mix well until about $\frac{1}{4}$ pint turpentine has been incorporated.

(*b*) *White Lead Paint*. To 2 lbs. white lead paste (as bought) add 2 teaspoonfuls of paste driers and 2 tablespoonfuls of linseed oil. Mix. Then add 2 tablespoonfuls of turpentine and mix well.

When made in this way these paints have the most suitable consistency for application to tree wounds. Both paints dry quickly and give a good cover which does not crack until a long time after application. The " surface " given by this red oxide paint is nearly as good as that of antifouling paint. Neither of these paints causes greater damage to the bark of young trees than the corresponding paints sold ready for use, and in a considerable number of

wounds protected by them there has been no evidence of toxicity at all. Both of these paints prevent to a very great extent infection by *S. purpureum.* Thus out of fifty wounds treated with the home-made red oxide paint and inoculated with spore emulsions within a few days, only four have become infected. Of forty-four wounds covered with home-made white lead paint and subsequently inoculated only one has become infected. When it is remembered that the spore emulsion used is crowded with spores and that two applications of spores are applied to each of the wounds, these results are very striking. Of the two home-made paints white lead is to be preferred, as it facilitates callus formation and is generally less toxic to the bark than red oxide paint ; on the other hand white lead paint is a little more expensive than the other.

Soft Grafting Wax. This substance is used extensively in nurseries to cover wounds made in propagating fruit trees.* It has been used on a large scale in our experiments. Soft grafting wax is fairly easy to apply to wounds of limited size, is not readily affected by the weather, is not poisonous to the bark, and as it tends to keep the tissues moist, it facilitates the formation of callus.

In one series of experiments with this substance wounds made at different times of the year and immediately covered with it were inoculated a month later with a spore emulsion of *S. purpureum.* None of these became positively infected. After the lapse of a reasonable period these twigs were cut up ; it was invariably found that the wood for a distance of about half an inch to one inch below the surface was discoloured, there being a blackish " gum barrier " on the margin of the discoloured zone. The discoloured wood contained hyphae of various kinds, but the characteristic mycelium of *S. purpureum* was only rarely seen. It is clear that fungi had invaded to a limited extent the tissues below the wax, but had not penetrated sufficiently to be dangerous.

In several other series of experiments carried out in different months the spore emulsion was applied a few days after protecting the freshly cut wounds with grafting wax. Only one wound protected with soft grafting wax has become artificially infected with *S. purpureum* throughout all these series of experiments. In view of this result soft grafting wax can be confidently recommended as a wound protective, especially to cover small wounds to which it can be applied with ease. It is not so easy to cover large wounds with grafting wax and for this purpose one of the home-made paints, which can be applied with a brush, is preferable.

Tar. In the previous paper (3) it was pointed out that Stockholm tar had given very poor results as a wound protective. Further experiments having confirmed this, its use has been discontinued.

* The use of soft grafting wax was recommended to us by Mr. G. N. Bunyard of Maidstone.

At first gas tar gave better results than Stockholm tar, but with greater experience of this substance we have had to modify our opinion of its value as a wound protective. Besides, although gas tar is often innocuous to the bark of plum trees it frequently causes considerable damage to relatively young apple bark. During the last two years many additional experiments have been carried out to ascertain what measure of protection against *S. purpureum* is afforded by gas tar. For this purpose two to three year old twigs of Czar plums have been cut back at monthly intervals and immediately covered with gas tar, a spore emulsion being applied two days and again four days after protection. This set of experiments was carried out at the same time as those to determine the chances of infection of unprotected wounds by *S. purpureum* month by month throughout the year. At most times of the year infection took place as readily through the gas tar as through unprotected wounds, but the results also showed that protection of wounds by gas tar during July and August actually facilitates infection by *S. purpureum*. This is a surprising result, but it has been obtained for two successive seasons, so it cannot be ignored. It will be remembered that infection of unprotected wounds during these summer months is unlikely to occur. Possibly the presence of the tar tends to keep the tissues below moister than in unprotected wounds, and it may be that the influence of the tar tends to prevent the formation of a "gum barrier", which often prevents infection at this time of year.

In another series of experiments wounds of the same kind cut in January, April, July and October were immediately covered with gas tar, and inoculated with a spore emulsion either a week, a month, three months, or six months afterwards. The results for infection through unprotected wounds made at the same time and inoculated in the same way have already been given. Again with wounds covered with gas tar there were as many positive infections as with unprotected tissues. There was also some evidence that the addition of gas tar tended to keep the wounds in a condition susceptible to infection for a longer period than usual. Thus whereas no unprotected wounds became infected after three months' exposure, several of those covered by gas tar for this period did become infected.

When gas tar is applied to a fresh exposure, much of it is sucked a considerable distance into the vessels. However toxic tar in the free state may be to fungi, it is obvious in the light of the above results that when applied to woody tissues its toxicity is not sufficient to prevent *S. purpureum* germinating in association with it and growing through tissues impregnated with it, even when the spores of the fungus are added a few days after the tar has been applied. Upon cutting sections of the wood over which the tar has been placed and spores subsequently added, the hyphæ of the fungus can be seen side by side with drops of tar in the vessels.

In the light of these results one is forced to the conclusion that gas tar, like Stockholm tar, is entirely inefficacious in keeping *S. purpureum* at bay.

Other substances used as Wound Protectives.

Many other substances have been tried as wound protectives, but all of these were soon discarded owing to some defect. Only the briefest mention will be made of these substances.

Collodion. This, dissolved in a mixture of equal parts of alcohol and ether, forms a good film over the surface of wounds, but after a short time the film flakes off and the tissues become exposed. The substance is also difficult to prepare in a suitable form.

Tanglefoot. This and other greasy substances are difficult to spread over wounds.

Water-glass (*cf.* Young (22)). This does not form a good film over wounds. and after about three weeks it dries to such an extent that the wounds appear not to have been covered at all.

Shellac. Shellac dissolved in commercial methylated spirits gives an apparently good surface at first, notwithstanding which infection by *S. purpureum* has taken place through it with some ease. After three months the shellac flakes off in irregular patches.

Asphaltum. This was recommended by Dr. H. Wormald. Dissolved in benzine it gives a good black surface, but this is inclined to break up after about two months. Owing to difficulty experienced in incorporating the right amount of benzine to make a thick paste no very extensive trials with this substance have yet been made.

Sealing Wax. This readily adheres to wounds and does not flake off for a long time, but owing to the necessity of using a flame for its application it was discarded.

Mixture of Potassium Bichromate and Copper Sulphate. Chavestelon (7) claims that a 6 per cent. solution of potassium bichromate mixed with a 6 per cent. solution of copper sulphate is an efficient wound dressing for vines.

The cut ends of plum twigs have been treated with this mixture, but infection by spores of *S. purpureum* was readily induced through it, so it is of little or no value for protection against this fungus.

Rubber Latex. Latex of the Para rubber tree is now available in large quantities in this country, it being kept in a liquid condition by the addition of ammonia. Upon placing it on the cut extremity of a twig it rapidly coagulates, giving what appears to be an impervious coat. More rapid coagulation is, of course, caused by the addition of weak acetic acid, but if this be used, the film

is more irregular than when coagulation takes place naturally. The liquid latex can be easily applied with a brush, but one drawback to its use is that on sloping wounds it is so fluid that most of it runs off the cut. Experiments show that latex is not effective in preventing invasion by *S. purpureum.*

IV. THE FORMATION OF GUM IN PLUM TREES.

As is well-known, plum trees are prone to form large quantities of gum, which frequently exudes in masses from the trunk and branches. Preliminary observations on the formation of gum in the genus *Prunus* have been recorded in " Silver-leaf Disease, IV." (3), in which it is stated that gum-formation is a general pathological phenomenon not always associated with attack by a parasite. Since that paper was written, further work has been done on the mode of gum formation in plum trees. A summary of the investigations on gum formation in woody tissues up to 1922 is given by Czapek (12). Some of the investigators therein referred to consider that the gum comes from the membranes while others hold the view that it is formed from the cell contents.

It is important to distinguish the process of gum formation in meristematic and embryonic tissues from that in lignified tissues. In the former the whole of the cell walls and carbohydrate contents in the cells become converted into masses of gum (gum pockets) as described by Butler (6). In lignified tissues most of the gum, according to our experience, is formed from the carbohydrates in the cells, only a small amount being produced by the gummification of the surfaces of the walls bordering on the lumina of the cells. In the process of gum-formation in lignified tissues the cell walls generally remain essentially intact, quite unlike their complete dissolution in the formation of gum pockets.

The initiation of gum-formation in connection with wounds in plum trees has been followed carefully by examining longitudinal sections of plum wood from a few hours to a few days after exposure in October. After six hours' exposure small yellow blobs appear in the starch grains of the medullary rays just below the surface of the wound ; these stain brown with ammoniated fuchsin and represent the beginning of gum-formation. After two days' exposure the zone nearest the surface contains the yellow, gummy substance both in the ray cells and in the vessels ; below this is a zone in which the gum is present only in the rays ; and below this again no gum is seen. After a month's exposure gum-formation occurs in progressively deeper tissues, the sequence being the same as before. After this interval the outlines of the starch grains originally present in the ray and wood parenchyma cells near the surface are obliterated and no reaction for starch is obtained upon staining with iodine, the starch having been completely replaced by irregular masses of gum. The gum formed in the vessels during the interval is chiefly derived from soluble carbohydrates already

therein or from those which diffuse into them from the ray cells after hydrolysis of the starch. During October, when these experiments were carried out, it must be remembered that the rate of discoloration of the tissues below the exposure is comparatively slow. During the summer the sequence of events is more rapid. In the early stages of the formation of a " gum-barrier " the medullary rays in the immediate vicinity lose most of their starchy contents by hydrolysis, most of the soluble carbohydrates passing into the vessels, to be deposited as dense masses of gum. In a " gum-barrier " comparatively little gum is laid down in the medullary ray cells themselves. It has already been pointed out that the " gum-barrier " is laid down just beyond the limits reached by the mycelium. If a wound be inoculated with a spore emulsion of *S. purpureum* immediately after exposure, the course of events in respect to gum formation is the same except that gum is formed more copiously and more rapidly once the initiation of infection has begun.

It is interesting to note in this connection that Dorsey and Strausbaugh (14), investigating winter injury to plum trees in N. America, found that the storage materials of the wood were in part transformed into gums and tannins by injury of this kind.*

Coster (9) has recently investigated the formation of gum in woody tissues of the teak tree in response to injury. He maintains that the gum-like substances are formed indirectly from starch. This is essentially the view put forward by Brooks and Bartlett (5) and by others, which has been advocated in earlier papers of this series. Coster (9) also concludes that in teak the ray cells must first be dead before the starch can be changed into gum, the wound reaction of living cells being to form tyloses. In plum wood it is very doubtful whether the ray cells are dead at the times of the initiation of gum-formation, which, as pointed out above, begins within six hours of wounding. Gum formation in connection with fungal invasion proceeds in advance of the mycelium, and again it is doubtful whether in the early stages of this process the ray cells are dead. One important difference between teak and plum is that in the latter tyloses are practically never formed, the universal response in the plum to pathological conditions of whatsoever kind being the formation of gum.

V. NATURAL RECOVERY OF SILVERED FRUIT TREES.

Attention was called in " Silver-leaf Disease, IV." to the frequent recovery of susceptible varieties of plum from the disease in certain seasons. It was pointed out that this recovery was due to the progress of the fungus in the tissues having been impeded by the formation of a " gum-barrier," with the result that in time the fungus died. This interpretation of the immediate cause of recovery has been abundantly confirmed during the past two years.

* We are indebted to Prof. J. H. Priestley for calling attention to this paper.

It is only trees of a certain vigour of growth that recover in this way without treatment, and it is reasonable to suppose that only such trees can effectively form the "gum-barriers" which bring about the defeat of the fungus.

Recovery from the disease is more pronounced after a dry season, doubtless owing to the more ready formation of "gum-barriers" then. Why this thould be so is not yet known, and an explanation of the phenomenon is not likely to be forthcoming until there is a much fuller knowledge of the physiology of woody plants than exists at present.

It can at any rate be confidently stated that the chances of recovery from silver-leaf disease depend chiefly upon the vigour of the tree. Affected trees growing in poor soil or lacking in root development practically never recover, and sooner or later are killed by the disease.

There is no doubt that the amount of recovery from this disease is considerably greater than was formerly believed to occur, even with susceptible varieties of plums such as Victoria and Czar. One group of Czar trees (about fifteen years old) in grass which has been under observation for the last three years has given the following results :—

		Number healthy, 1925.	Percentage recovery.
Slightly Silvered, 1922 ..	19	13	68
Moderately Silvered, 1922 ..	23	15	65
Heavily Silvered, 1922 ..	11	0	0
Total..	53	28	53

Thus more than half the trees which were slightly or moderately silvered in 1922 are now healthy. These trees have received no special treatment and have not been manured in any way. It will be noted that none of the trees originally badly affected by the disease have completely regained their health ; this has been noted on other occasions also, and there seems to be a certain degree of attack beyond which it is almost hopeless to expect recovery.

Another way of attempting to evaluate the amount of recovery in this group of trees is as follows :—

Marks were assigned to the trees according to the following scale :

Healthy	0	
Traces of silvering	1	(None of the trees showed traces only in 1922),
Slight silvering	2	
Moderate silvering	3	
Heavy silvering	4	
Killed by the disease	5	

From a comparison of the marks assigned in 1925 with those in 1922 the percentage recovery can be calculated. The recovery amounts to 54 per cent., which again is very considerable for the whole group of fifty-three trees.

As a contrast to the result just outlined the behaviour of another group of Czar trees of about the same age, growing within a mile under conditions of clean cultivation, but much less vigorous, may be mentioned. Here of ninety-three trees which were moderately silvered, only one recovered from the disease, twenty-four remained silvered to approximately the same extent, and no less than sixty-eight died within a period of two or three years.

The vigour of the tree is therefore a potent factor in determining whether silver-leaf disease is to have a fatal issue or not.

Another illustration of the potency of natural recovery where trees are growing vigorously may be given from the East Malling Research Station records by courtesy of Mr. R. G. Hatton :—

	Trees moderately silvered in 1922.	Healthy in 1925.
Pershore	18	14
Victoria	22	10
Giant Prune	8	6
Czar	22	19
Purple Egg	7	7
Total	77	56

These trees, which were planted as maidens in 1921, were not treated in any special way. It will be seen that more than half of them have entirely recovered from the disease.

VI. EXPERIMENTS ON THE AMELIORATION OF SILVER-LEAF DISEASE.

(1) Experiments with Manures.

In view of the considerable amount of natural recovery from this disease it might be expected that the recovery-rate might be increased by appropriate manurial treatment of silvered trees through causing enhanced vigour. At present little information is available as to the response of fruit trees to manurial treatment, and in the absence of such guidance some of the commoner substances used in agricultural practice have been employed.

In one experiment at Melbourne a group of 116 moderately or heavily silvered Czar plum trees, about fifteen years old, and growing in grass, have been under continued observation and treatment during the past three years. These trees were on good land (loam overlying chalk) and were of fairly vigorous growth, as

shown by the abundance of new shoots put forth from time to time. Groups of ten of these trees were treated with kainit, basic slag, or sulphate of ammonia, either separately or in combination, at the rate of 4 lbs. each per tree, two applications being given in December and March respectively in each of the years 1922-3, 1923-4, and 1924-5. At the same time forty-six of these silvered trees were retained as controls without treatment. For the purpose of evaluating results points were assigned to the trees according to the scale previously mentioned, viz.:

Healthy	0
Trace of silvering	1
Slight silvering	2
Moderate silvering	3
Heavy silvering	4
Dead	5

Comparisons were made year by year, and the percentage amount of recovery calculated.

The following are the results after treatment for two and three years respectively:

No. of Trees.	Treatment.	No. of trees which have totally recovered since 1922.		Percentage recovery on point system.	
		1924.	1925.	1924.	1925.
10	Kainit, Basic Slag, Sulphate of Ammonia	3	7	45	76
10	Kainit, Basic Slag	4	7	63	85
10	Kainit	4	6	49	58
10	Kainit, Sulphate of Ammonia ..	2	5	22	44
10	Basic Slag, Sulphate of Ammonia	5	6	73	61
10	Basic Slag	3	5	44	59
10	Sulphate of Ammonia ..	3	3	27	21
46	No Treatment (CONTROL) ..	14	18	44	51

The noticeable feature of these results is the enhanced recovery shown in 1925 by trees treated with kainit + basic slag + sulphate of ammonia, and with kainit + basic slag. On the other hand, treatment with sulphate of ammonia appears to have depressed the rate of recovery, and neither kainit nor basic slag alone appears to have had appreciable effect. It must be remembered that heavier applications of these manures have been given than would be applied in ordinary commercial practice, and that no less than six applications of each manure have been given. Even the benefit apparently accruing from treatment by kainit and basic slag in combination is of doubtful commercial value in view

of the cost involved. The experiment has, however, been continued for three years to show what is the probable value of manuring silvered, but fairly vigorous fruit trees under critical conditions of observation.

As a contrast to the above experiment silvered plum trees at Melbourne, weak in growth and situated on poorer land in clean cultivation, were manured in various ways. The trees were chiefly Czars, but a few Monarchs were included. They were of about the same age as the trees referred to in the previous experiment. Two applications of each kind of manure were given in December and March in each of the years 1923-4 and 1924-5. The same amounts of artificials were given, and with farmyard manure liberal dressings were applied. In view of the large number of silvered trees which died in the course of this experiment, it is not worth while to attempt to evaluate the results on the point system.

The results were as follows :

(1) *Treatment with kainit.*

16 trees were treated ; of these 10 were moderately, and 6 heavily silvered at the commencement of the experiment. In September, 1925, the condition was :

9 dead (8 died in 1924).
4 heavily silvered.
2 moderately silvered.
1 slightly silvered.

(2) *Treatment with basic slag.*

16 trees were treated ; of these 4 were slightly, 8 moderately, and 4 heavily silvered at the commencement of the experiment. In September, 1925, the condition was :

11 dead (10 died in 1924).
4 heavily silvered.
1 moderately silvered.

(3) *Treatment with kainit + basic slag.*

15 trees were treated ; of these 4 were slightly, 6 moderately, and 5 heavily silvered at the commencement of the experiment. In September, 1925, the condition was :

10 dead (8 died in 1924).
2 heavily silvered.
2 slightly silvered.
1 healthy.

(4) *Treatment with sulphate of ammonia.*

18 trees were treated; of these 6 were slightly, 6 moderately, and 6 heavily silvered at the commencement of the experiment. In September, 1925, the condition was:

9 dead (all dead in 1924).
1 heavily silvered.
4 moderately silvered.
1 slightly silvered.
3 healthy.

(5) *Treatment with farmyard manure.*

18 trees were treated, twice in 1923-24, and once in 1924-5; of these 4 were slightly, 10 moderately, and 4 heavily silvered at the commencement of the experiment. In September, 1925, the condition was:

9 dead (7 died in 1924).
1 heavily silvered.
4 moderately silvered.
2 slightly silvered.
2 healthy.

(6) *Control.*

14 trees, all of which were moderately silvered at the commencement of the experiment. In September, 1925, the condition was:

5 dead.
6 heavily silvered.
2 slightly silvered.
1 healthy.

These results indicate that it is useless to manure silvered fruit trees the growth of which is poor. These trees, including those in the control, have deteriorated rapidly, and afford a striking illustration of the damage which can be done by this disease to plums of weakly growth.

Another experiment on the effect of manurial treatment of silvered plum trees has been carried out in Worcestershire by Mr. G. C. Maltby, with the co-operation of one of the writers. The trees were very large Victorias, about fifty years old, and still fairly vigorous notwithstanding their age. They were growing on a heavy loam overlying lias. During the winters of 1923-4 and 1924-5 the trees were treated twice, in December and April, with kainit or basic slag or with a combination of these, at the rate of 8 lbs. of each per tree per application. Marks have been assigned to these trees on essentially the same

basis as in the Melbourne experiment on trees in grass, and the percentage recovery or deterioration calculated. The results are :

No. of Trees.	Treatment.	No. of Trees which have totally recovered since 1923.		Percentage recovery (+) or deterioration (—) on the point system.	
		1924.	1925.	1924.	1925.
12	Kainit	3	5	+29	+13
12	Basic Slag	6	6	+58	+47
12	Kainit and Basic Slag	1	1	—21	—39
17 (i.e. 8 + 9)	Control (Plots B. and E. together)	4	5	+ 6	+ 8
8	Control (Plot B.)	4	5	+47	+63
9	Control (Plot E.)	0	0	—21	—24

In this experiment basic slag is associated with the best results, but, in contrast with the experiment on trees in grass at Melbourne, treatment with a combination of kainit and basic slag has been followed by an increase in the disease. The difference in behaviour of the two control plots (B and E), however, shows how hazardous it is to draw conclusions from the behaviour of small numbers of trees.

In all the manurial experiments outlined above it must be remembered that the number of trees receiving any one specific treatment is small, and that, in consequence, the experimental error is large. The difficulty, however, in getting larger numbers of trees to work with is very great and probably insuperable.

To sum up the results of these manurial trials so far, one may say that with silvered trees of average vigour there is some chance that treatment with basic slag will assist recovery, and to a lesser extent this is true of kainit. On other classes of soils the results may be different. What is wanted is treatment that will produce the maximum vigour of growth, for it is under such conditions that the tree tends most to recover from the disease. The fruitgrower will usually be the best judge of what is most likely to be efficacious in this respect. On the other hand, with silvered trees that are weakly in growth it is useless to treat them manurially in the hope of facilitating recovery.

Claims are sometimes made that certain proprietary substances when applied to the soil will cure silver-leaf disease. Those who make these claims frequently ignore the fact that fruit trees not uncommonly recover from the disease without treatment. Some of these claims have been investigated on a large scale with an adequate control, and although these trials are not yet complete, one can state confidently that, as far as the investigations have proceeded, none of these claims have been substantiated.

(2) EXPERIMENTS WITH RING BARKING.

It is sometimes claimed that silver-leaf disease can be cured by cutting away a narrow ring of bark two-thirds or three-quarters around the circumference of the silvered branch or main stem if the tree be generally silvered, the ring being made a short distance below the level which, it is supposed, the fungus has reached. We have seen small numbers of trees which have been treated in this way and have subsequently recovered, but in these cases there has been no adequate control experiment.

Large-scale experiments are now in progress to try to determine whether ring-barking can be looked upon as a means of cure or of facilitating recovery. One effect of ring-barking is to cause a disturbance in the normal flow of food substances in the wood and bark in the vicinity of the ring, which may indirectly impede the progress of the fungus. Again, in ring-barking, profuse quantities of gum exude from the ring as a wound response and are also found in the adjacent tissues. These masses of gum which collect in the wood may perhaps mechanically prevent the progress of the fungus as in the formation of "gum-barriers" referred to in the earlier part of this paper, and thereby bring about the defeat of the parasite. Those who advocate ring-barking as a means of control suggest that the gum which accumulates in the ring should be removed from time to time. This was done in our experiments.

The experiments which have been made in this connection are not all complete, but it is desirable to give the results which have accrued to date.

In the first experiment the trees were chiefly Czar plums with a few Monarchs about fifteen years old, growing rather weakly in clean cultivation. Sixty-eight of these trees, all of which were moderately or heavily silvered, were selected in 1922. In June, 1923, eighteen of these were ringed once either towards the base of the silvered branch or on the main stem at a level below that to which it was believed the fungus had reached, the ring being one-quarter to half-an-inch wide. Twenty-eight others were ring barked twice on the same date, with an interval of about six inches between the two rings, the intact portions of bark in the rings being on opposite sides of the branch or main system. The remaining twenty-two trees were left as a control.

The condition of the trees in September, 1925, was as follows :—

Trees ringed once (18).

10 dead.
5 heavily silvered.
1 moderately silvered.
1 slightly silvered.
1 healthy.

Trees ringed twice (28).

20 dead.
3 heavily silvered.
1 moderately silvered.
1 slightly silvered.
3 healthy.

Control (22).

14 dead.
4 heavily silvered.
1 moderately silvered.
1 slightly silvered.
2 healthy.

It is clear that in this experiment, in which the trees were of rather weak growth, ring-barking has not helped to stay the progress of the disease.

In another large-scale experiment the trees (Victoria plums) were ring-barked soon after the trees were inoculated with *Stereum purpureum*, to ascertain whether the ringing would have any effect in preventing the development of the disease. These Victorias were about eight years old, and were growing vigorously. Fifty-four of these trees were inoculated in December, 1924, and thirty-seven of them were ring-barked either once or twice below the place of inoculation soon afterwards, the remaining seventeen being inoculated, but not ring-barked.

The results in September, 1925, were :—

Trees ringed once (19).

1 heavily silvered.
10 moderately silvered.
5 slightly silvered.
3 healthy.

Trees ringed twice (18).

12 moderately silvered.
5 slightly silvered.
1 healthy.

Control (17).

10 moderately silvered.
6 slightly silvered.
1 healthy.

It is too early to draw conclusions from this experiment, although it is clear that ringing does not prevent the development of the disease. As far as the

experiment has gone, there is no difference in the reactions of the three groups of trees.

Until the result of this experiment on vigorous trees is complete, we must retain an open mind on the efficiency of ring-barking, although as far as our experiments have yet gone, we see no reason to recommend this practice as a means of alleviating silver-leaf disease.

A considerable experiment also on these lines was carried out at East Malling Research Station in 1923 in co-operation with Mr. R. G. Hatton. Forty-eight plum trees of different varieties, which were silvered in 1922, were ring-barked in April, 1923, forty-eight trees equally silvered being kept as a control. All these trees were growing well. The results in 1925 were :—

	No. of Trees Ringed.	Complete recoveries in 1925.	No. of Control Trees.	Complete recoveries in 1925.
Pershore	16	11	16	11
Victoria	17	3	17	3
Giant Prune	4	4	4	3
Czar	6	3	6	3
Purple Egg	5	5	5	5
	48	26	48	25

There is no significant difference in the recoveries in the two sets of trees.

VII. TREATMENT.

It has long been advocated in this series of papers that one of the most important measures to take in regard to silver-leaf disease is to prevent the fungus from fructifying within and on the confines of fruit plantations. This attempt to abolish the more direct sources of infection in accordance with the principles of plant sanitation has now been enforced for some years by administrative order of the Ministry of Agriculture and Fisheries, with the result that in the chief fruit-growing districts of the country thousands of fruit trees, killed by the disease, have been removed from being a menace to healthy trees in the vicinity. It is more difficult to ensure the destruction of the fungus on the stumps of trees, particularly birch, poplar and willow, just outside the limits of fruit plantations, but every effort should be made to do this. It is, of course, impossible to destroy completely such a ubiquitous fungus as *S. purpureum*, but we are convinced that the action taken by the Ministry of Agriculture and Fisheries in recent years has been the means of checking to some extent the alarming increase of the disease which was prevalent a few years ago.

The Silver-leaf Order of 1923 insists that dead wood in fruit plantations liable to harbour *S. purpureum* should be cut out by July 15th. The cutting out of dead wood in the early summer was formerly suggested both because it is more easy to see then the difference between dead and living branches, and because at that time of the year the fruiting bodies of *S. purpureum* are least abundant in a sporing condition. Our work of the last two years has also shown clearly that in the months of June, July and to a lesser extent, August, it is almost impossible for *S. purpureum* to cause infection of a fresh wound. For this reason also the cutting out of dead wood—for this often results in the exposure of healthy tissues, should be carried out in the early part of the summer. It is best to cut out the dead wood from otherwise living trees in June rather than July, because this gives a period of about two months before the fungus is again readily able to cause infection, and because it has been shown that in any case a wound exposed for more than a month is but rarely invaded by *S. purpureum.* From every standpoint therefore the cutting out of dead wood in living fruit trees should be done in June rather than at any other time of the year. If the work cannot be completed then, it should be finished as early as possible in July. The same argument of course applies to the thinning out of branches in healthy trees. Hitherto most of the thinning and pruning of fruit trees has been done in the winter, but there is now ample evidence that from the standpoint of plant pathology this is fundamentally wrong. These operations have been performed in the winter because other work is less pressing then, but the point of view on this connection should be revised in the light of the results recorded in this paper. From the standpoint of pressure of work fruitgrowers will probably find it easier to cut out dead wood in June rather than July. On the other hand, it is dangerous to cut out dead wood and other branches in May, as during that month the fungus often readily causes infection.

In connection with the cutting out of dead wood in fruit plantations, it may be mentioned that the writers have never seen fructifications of *S. purpureum* developing upon branches of plum trees killed by *Sclerotinia cinerea*, *Diaporthe perniciosa*, or *Cytospora sp.* It is, however, good husbandry to cut out these dead branches, whether they are liable to produce fructifications of *Stereum purpureum* or not.

The advisability of cutting out silvered branches of fruit trees depends chiefly upon their condition and upon the skill with which the operation is effected. If the trees are growing well, it is usually best not to cut out the silvered branches unless these have begun to die back, for, as has been shown in the earlier part of this paper, there is a reasonable chance of complete recovery in the course of time. With apple trees the chances of recovery are particularly good. We are aware, however, that some fruitgrowers, who take particular care of their plantations, have controlled the disease successfully by cutting out

in the early summer (June and July) branches of plum trees in the initial stages of silvering. Where branches are actually dying back they should of course be cut out in June and early July wherever possible. A few branches or occasionally entire trees may die from this disease between mid-July and the autumn. In such cases the dead wood should be destroyed without delay to prevent the fungus from fructifying.

Plum branches frequently break when they crop heavily, and the branches are sometimes broken by careless gathering of the fruit. Such wounds are a prolific source of infection of silver-leaf disease unless attended to. Branches which have been broken should be cut back flush with a larger branch or with the main stem immediately after the fruit has been gathered. In some plantations of heavy cropping varieties of plums like Victoria or Czar, it is now the practice to support the over-laden branches in some way or other, and this is the means of preventing a good deal of breakage.

Wounds should, of course, be protected either with soft grafting wax or with one of the paints described in the earlier part of this paper. In view of the results of our experiments gas tar as well as Stockholm tar should no longer be used as a wound protective, as it has been found entirely ineffective in preventing infection by *S. purpureum*, If a wound protective is to be used successfully it must be applied immediately after the wound is made, as that is by far the most susceptible time for invasion by *S. purpureum*. In nurseries particularly it is of the utmost importance to protect wounds made in propagation.

Anything that will stimulate the growth of silvered trees will be advantageous in facilitating recovery from the disease. Good cultivation and effective drainage are essential if the trees are to have a reasonable chance of throwing off the disease. On some soils the addition of a phosphatic or potash manure may be advantageous in increasing vigour.

We have also seen many fairly badly silvered trees recover after the following treatment. The most heavily silvered branches have been cut out in the early summer with a view to diverting the available food to a smaller number of slightly silvered or healthy branches. The result has been so to increase the vigour of the branches which remain that the tree has completely recovered and has, so to speak, been built up anew. In this connection it should be pointed out that badly silvered trees frequently give rise to new shoots immediately below the junction of branches and trunk, which assist in this process of the re-creation of the tree. This is not an operation which can be universally recommended, because great care is needed in the selection of the branches to be retained for the purpose of rebuilding the trees, but, for a fruitgrower who has the time and inclination to work upon his trees as individual units, this procedure can be recommended.

It is particularly important in plum growing to select soils favourable for growth, and trees which have been worked upon known stocks, preferably Pershore, Brussels, Brompton, Myrobolan B., or Common Plum by reputable nurserymen. Then if silver-leaf disease intervenes during the subsequent development of the plantation, the trees will probably possess sufficient vigour of growth to throw off the disease to a great extent. With the large extension of fruit-growing in this country during the last thirty years plums have not infrequently been planted in unsuitable soils with the result that when attacked by silver-leaf disease they have succumbed without a struggle.

VIII. EXPERIMENTS ON THE TOXIC INFLUENCE OF *STEREUM PURPUREUM* ON THE SHOOTS OF TREES.

It is well-known that the manifestations of silver-leaf disease in fruit trees are frequently exhibited above the region of the woody axes invaded by the fungus, and, as pointed out in the fourth paper of this series (3), signs of the disease occasionally appear below the region permeated by the fungus. On the other hand *S. purpureum* sometimes kills trees, e.g., beech and birch, without there being any preliminary symptoms of silvering of the foliage (1, 2), and as recently described by Cotton (10) in Rhododendron.

The usual silvering of the foliage on twigs unoccupied by the fungus is one of the best-known examples in plant pathology of action at a distance. These symptoms are usually explained by supposing that the fungus in its growth in the woody parts secretes a substance which, upon being carried to the leaves in the transpiration current, causes, either directly or indirectly, the phenomenon of silvering owing to the separation of the cells one from the other through the dissolution of the middle lamella. Tutin (20) has shown the pectin content of silvered leaves is less than in healthy leaves. Microscopic examination of a recently expanded silvered leaf shows that the chloroplasts are normal, the alteration in appearance of the leaf being a purely optical effect. At a later stage, however, many silvered leaves show a distinct yellowing of parts of the lamina. This may be followed by the browning of parts of the yellowed areas or of the whole leaf in the case of severe attack. The yellowing parts of a silvered leaf contain chloroplasts undergoing disorganisation and the brown areas denote regions of dead cells. It is evident therefore that the influence of the fungus on the leaves is a complex one, involving several different types of changes.

Mayo (17) in investigating the enzymes of *Stereum purpureum*, has shown that although a pectosinase is present, it is produced in relatively small amount. It is probable that the dissolution of the middle lamella of the leaf cells, which leads to silvering, is not caused directly by the pectosinase secreted by the

fungus, but through the liberation of pectosinase in the cells themselves, stimulated by some other substance or substances carried to the leaves by the activity of the fungus below. The same substances at a later stage and in greater concentration may also indirectly produce the other pathological effects evident in the leaves.

On the assumption that substances are secreted by the fungus in the woody tissues which, upon being carried up in the transpiration current, produce these pathological effects in the leaves, it might be supposed that an extract of the fungus, or, alternatively the culture fluid in which the fungus has been growing, would produce similar effects upon the foliage of a plum tree when injected into the woody parts, or upon the foliage of twigs when these were placed in one or other of these fluids. Many experiments have been carried out in this connection.

In one series of experiments the fluid used was an asparagin-glucose-mineral salt medium in which the fungus has been growing about two months, filtered through a Buchner bougie. Plum twigs with buds just beginning to expand were placed in the fluid, which was renewed at frequent intervals and which was kept from contamination as much as possible. Similar twigs were kept in distilled water. Preliminary experiments had shown that it was necessary to cut off daily about half-an-inch of the part of the twigs immersed in the fluid in consequence of the rapid formation of gummy substance at the absorbing extremity, which prevented the free uptake of the fluid, and which alone might cause wilting. The control twigs were treated in the same way, although the formation of gum at the cut extremities of these was much less. Within a week the expanding leaves of the twigs in the filtered culture fluid showed brown patches around the margin, especially at the tip, and were beginning to wilt, whereas the leaves of the control twigs were entirely unaffected. After ten days all the leaves of the twigs in the culture fluid had wilted and the discolouration was more pronounced, whereas the leaves of the control twigs were still normal. It seems clear therefore that the filtered extract of the fluid in which the fungus had been growing exercised a toxic influence on the leaves of the twigs immersed in it, although no silvering was apparent. The toxic influence here appeared similar to the last phases of silvered leaves in nature in which brown, necrotic areas become apparent.

In another experiment which was carried out when Mr. H. H. Storey was associated with these investigations, healthy plum leaves were placed in (*a*) distilled water, (*b*) boiled plum wood extract, (*c*) the filtered fluid from a culture of the fungus on plum wood. Three leaves were placed in each liquid. After two days all the leaves in the culture fluid were brownish yellow, one leaf in the boiled plum wood extract was somewhat yellowish, the other two being normal, and the leaves kept in distilled water were healthy. The result of this experiment

also points to a toxic influence exercised by the fluid in which the fungus had grown.

In June, 1923, four plum trees in pots were injected with the culture fluid in which the fungus had been growing for four months, the fluid being filtered through a Berkefeld bougie. For the injection a hole was bored into the main stem of the tree, just above soil level, and there was inserted into the hole a glass tube that led upwards to a reservoir in which the fluid was placed. The glass tube was sealed into the stem with plasticine. Control trees were injected with distilled water at the same time. Under these conditions the fluid was readily taken into the stem.* The first effects were seen after four days, when leaves on the same side of the tree as the injection began to turn brown at the margins and wilt, whereas the leaves of the control trees were normal. The inflow of the culture fluid ceased after six days, by which time many leaves on the side of the injection were wilted and brown. The cessation of intake was due to the formation of gum at the place of insertion of the glass tube. Here again there was definite evidence of a toxic influence on the part of the culture fluid, but the symptoms of silvering were entirely absent.

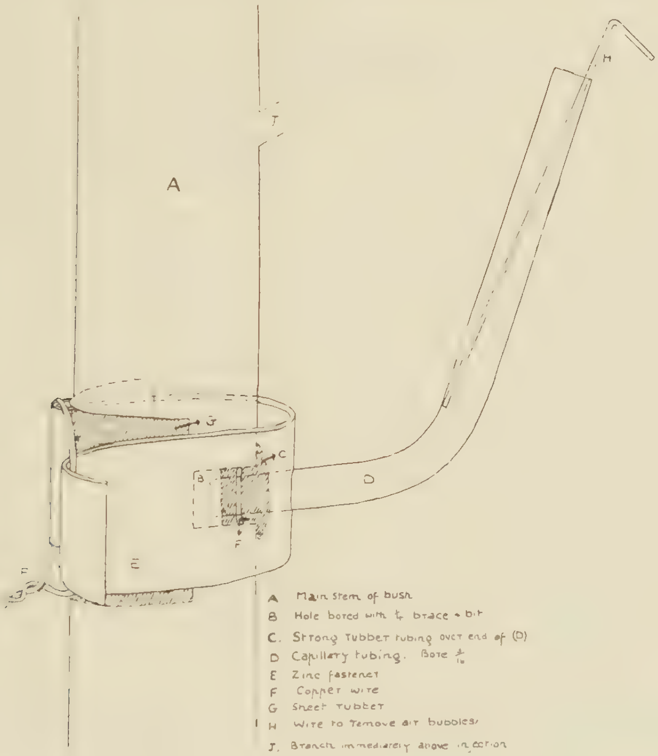
It was thought that perhaps the culture fluid was being used at too great strength so, after filtering, it was diluted to a quarter of the normal concentration and used for the injection of other trees. In this case no positive effect was observed.

In the summer of 1924 other experiments were carried out upon plum trees in a greenhouse. Under these conditions there was great difficulty in keeping the plasticine intact. Another drawback was that, owing to the large size of the reservoir, the culture fluid, notwithstanding careful filtering, became rapidly contaminated. Various modifications of the injection apparatus were tried, and finally one which was kindly suggested by Dr. G. H. Pethybridge was found entirely satisfactory. An annotated diagram of this apparatus (natural size) is reproduced on page 93.

Six plum trees were injected in this way, the place of injection being a short distance below a side branch. Owing to the smallness of the reservoir the filtered culture fluid had to be replenished frequently, but this had the advantage that bacterial contamination was considerably reduced. In five out of the six trees several leaves on the twigs immediately above the place of injection wilted and turned brown within six days of the beginning of the experiment, and other leaves which did not wilt showed within a few days a pronounced yellowish mottling. After fifteen days the intake stopped. It seems that here was evident the yellowing effect which is often apparent in silvered leaves before the development of the brown, necrotic areas.

* The readiness with which fluids are taken up by injection has been utilised by C. B. Lipman and A. Gordon. ("Further Studies on New Methods in the Physiology and Pathology of Plants," Journ. Gen. Physiol., p. 615, 1925.)

In 1925 modified experiments were carried out with the same apparatus, but this time the injections were commenced in March, when the buds of the trees in the greenhouse were just on the point of opening. In these experiments it was thought that the influence of the deleterious substances in the culture fluid might be more evident if they came into contact with the very young developing leaves, for it is known that the symptoms of silvering are best developed when the young leaves become silvered while within the bud. A difficulty in previous



experiments was the cessation of intake after about ten days, owing to the formation of gum at the wounded surface. This was overcome by making a series of injections one above another, at distances apart of about two inches, at weekly intervals, so that the opening buds in the upper region of the main axis were constantly under the influence of the injected fluid. As the tubes were removed from the lower holes the latter were filled with sealing wax.

In these experiments the culture fluid in which the fungus had been growing was filtered through ordinary filter paper as experience had shown that bacterial contamination could not be entirely avoided. Some of the fluid, however, was sterilised after filtration by boiling. Both the unboiled and the boiled fluid were

used in three concentrations : (1) normal, (2) one-fifth normal, (3) one-twentieth normal. Several trees were injected with each of these fluids, both in the greenhouse and on older trees in the open.

At the same time control experiments were carried out by using the sterile culture fluid which had not been inoculated with the fungus, and also by boring holes at intervals upwards in the stems of comparable trees to see if the partial interruption of the transpiration current had any effect.

All the injections with full strength culture fluid in which the fungus had grown, whether boiled or not, caused wilting and browning of the expanding leaves directly above the places of injection, with the same effect, but less marked, on buds in the near vicinity of the line of injection holes. In many cases too some of the buds immediately over the places of injection were killed outright. With the same fluids diluted to one in five and one in twenty, the same effect was still evident, except in the case of those which had been boiled. The effect of the injection of the fluid diluted to one in twenty was less marked than with that of greater concentration. In the control experiments no adverse effect was observed. These particular experiments lasted for six weeks. Although the more serious toxic effects were evident, there was no sign of silvering. If a young leaf did not become affected in the manner described at an early stage, it expanded normally and assumed a healthy green colour. In view of the adverse effect produced by the full strength culture fluid after boiling it would appear that the toxic substance was in part at any rate thermo-stable.

IX. SUMMARY.

1. Additional field observations upon the incidence of Silver-leaf disease are recorded. Attention is called to a slight increase of the disease upon roses, especially ramblers.
2. The ability of spores of *Stereum purpureum* to infect freshly exposed wood tissues of fruit trees has been tested throughout the year. It has been found that the fungus can generally infect fresh wounds readily throughout the year except during June, July, and August. The causes of non-infection in these months are probably related to the physiological condition of the host, which leads to the formation of a " gum-barrier " below the exposed surface ; this prevents the further progress of the fungus.
3. The ability of the spores of *S. purpureum* to infect woody tissues after varying periods of exposure has been tested throughout the year. It has been ascertained that it is very difficult for this fungus to infect exposures of a month's standing, and practically impossible for it to infect tissues which have been exposed for three months. *S. purpureum*

most readily infects woody tissues immediately after exposure. The causes of the failure to infect wounds after a certain lapse of time are discussed.

4. The bearing of these discoveries concerning the infectivity of *S. purpureum*, upon the practical treatment of the disease is discussed. It is urged that cutting out the dead wood or silvered branches (where the latter is advisable) and the thinning out of fruit trees should be done during the *early part of the summer*.

5. There seems to be no danger of *S. purpureum* following in the wake of an attack on plum trees by the fungi *Sclerotinia cinerea*, *Diaporthe perniciosa* and *Cytospora spp*.

6. The mode of formation of gum in response to wounding and to invasion by fungi, and the mode of development of protective "gum-barriers" is described.

7. It is pointed out that the amount of natural recovery from this disease is greater than was formerly supposed, even in susceptible varieties of plums such as Victoria and Czar. The amount of natural recovery has been correlated with the vigour of the tree. The immediate cause of natural recovery is the formation of a "gum-barrier" in the tissues which prevents the further growth of the fungus.

8. Experiments on the use of various protective substances for covering wounds in fruit trees are described. The best results have been obtained with soft grafting wax and with paints of a certain composition and consistency. The formulae for making these paints are given. Further research has shown that gas tar as well as Stockholm tar is an unsatisfactory protective.

9. The results of ring-barking silvered trees are recorded. As far as the results of the experiments are available they indicate that no considerable benefit is likely to accrue from this treatment.

10. The results of manuring silvered plum trees in various ways are given. Applications of basic slag and kainit have been found to benefit the trees in some instances, but it is too early to make a confident statement about the results of manurial treatment.

11. Treatment.

    (*a*) Continued treatment of the disease along the lines of plant sanitation is advocated ; i.e., the fungus should be prevented from fructifying in and on the confines of fruit plantations.

    (*b*) Cutting out of dead wood and living branches of fruit trees should be done in the early summer when the chances of infection by this

fungus are least. Broken branches should be cut out directly after the fruit is gathered.

(*c*) Fresh exposures of woody tissues should be covered immediately with soft grafting wax or with one of the paints described in the paper.

(*d*) The vigour of the trees should be maintained as high as possible by careful selection of land and young trees, and by suitable cultivation and manuring when the latter is necessary.

(*e*) A method is described by which health in silvered trees may be regained by stimulating the growth of branches arising lower down the tree than those badly affected by the disease.

12. It has been shown that the fungus in its growth secretes some substance which, apart from the living organism, will produce, when injected into healthy trees, some of the symptoms associated with the later phases of Silver-leaf disease.

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THE HEALING OF WOUNDS IN WOODY STEMS.

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INTRODUCTION.

In horticulture, agriculture and forestry, the cultivation of woody plants often involves the cutting back or removal of branches, and it is a matter of fundamental practical importance to know whether the entry of disease through the cut surface may be prevented. Pomology and fruit tree culture in particular also involves the frequent wounding of trees, not only by pruning away the ends of branches but also in such operations as budding, grafting, and ringing or girdling. The skilful use of the knife is in fact one of the principal arts in pomology and as the use of this instrument invariably involves wounding, it is essential that we have some knowledge of the processes involved in the natural closure of the wounds thus made. If the scale of practical operation permits, the cut surface may be covered immediately with an antiseptic dressing, although recent work (1 and 11) seems to have proved fairly conclusively that most of the dressings commonly used are valueless in this respect. In many cases, however, as also in the event of injury due to natural causes, the exposed surface must be left to heal itself. In such cases the entry of disease depends upon two main sets of factors, both controlled to some extent by weather conditions during the time following the exposure of the inner tissues. One of these sets of factors, the biology of parasitic organisms entering through wounds, has received very considerable study of recent years at the hands of pathologists. The other series of factors, connected with the internal resistance to injury provided by the natural processes of closing the cut surface, are under examination in this paper. When woody surfaces are exposed by pruning operations it is obviously possible to control the time at which such exposures are made. The natural process of healing has therefore been studied in wounds made throughout every month of the year, as the information thus gathered may give some guidance to the cultivator as to when to cut his trees.

The processes of healing in woody tissues are very different from those occurring in parenchymatous tissues. In the latter the cut surface is usually closed against the atmosphere within two or three days, in the sense that both intercellular spaces and living cells are cut off from the atmosphere by a continuous layer of fatty substances not easily penetrated by bacteria or the germ tubes of fungi, and relatively impermeable to water and substances dissolved in water (17 and 19). This layer of fatty substances, consisting mainly of the oxidation and condensation products of fatty acids, is generally

known as suberin (15), and is formed at the exposed surface, below the superficial layer of dead or dying cells.

When woody tissues are exposed, relatively little of the tissue at the actual surface of exposure consists of living parenchyma and no continuous layer of fatty substance accumulates near the cut surface. The greater part of the exposed surface consists of "dead" vessels and tracheids, and the first stage in healing consists in the gradual blocking up of the path thus opened to micro-organisms by the gradual stopping up of vessels and tracheids by a deposit within them of an insoluble substance. However brought about this process will be spoken of in the future as the "plugging" of the vessels.

If however the process is universal across the cross section of the wood near the cut surface, and if at the same time the parenchyma cells interspaced between the conducting elements of the wood are so altered that they prevent the movement of water through them when forced in under pressure, the whole branch will be spoken of as "blocked." Such a blocking of the woody surface is but the first step in the natural process of healing, the woody branch then becoming frequently the seat of a process of callus formation due primarily to the resumption of activity by the cambium in the neighbourhood of the wound.

For practical purposes it is probably all important to know when the branch has become primarily blocked in the sense in which this word is used above. This is the process which has been most thoroughly studied in the preliminary stage of this work. A decision as to the completeness of blocking based merely upon histological examinations might well be incorrect, and a simple experimental method has been devised which further tests this point.

EXPERIMENTAL METHOD.

Originally sycamore, beech, horse-chestnut, rhododendron, lime, red currant, raspberry, plum and apple stems were selected as material for study, but after a few months' investigation the work was restricted to sycamore, rhododendron, plum and apple, and the results given in this paper are obtained from these stems.

Branches between three and seven feet from the ground were cut off at a place where they were about three-quarters of an inch thick (i.e., between four and six years old). The cut surfaces were dressed smooth with a sharp knife and left exposed. A sufficient number of branches were so treated at the beginning of each month of the year as to allow the collection of one of them in every subsequent month. By this method it was possible to study the process of healing in wounds made in every month of the year, after these had been healing over any period from one to twelve months. The histological study has been carried out with pieces of these branches. Usually about four inches of

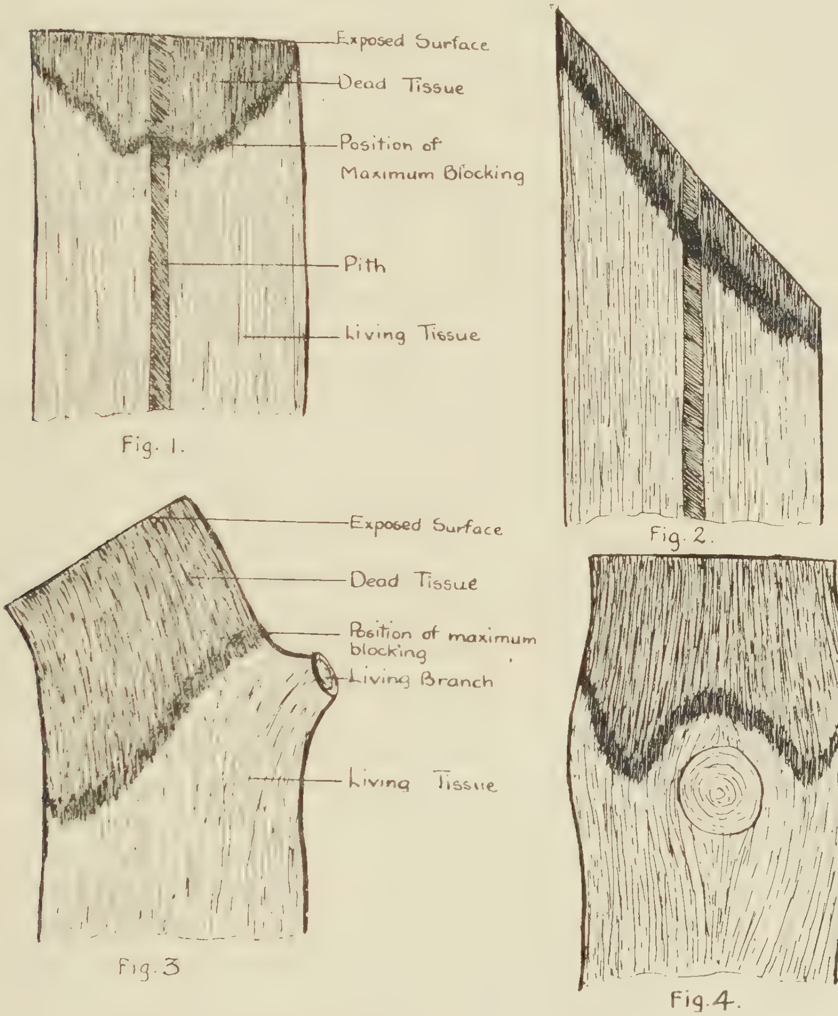
the stump was cut off and preserved in formalin-alcohol. Using a Jung Sliding Microtome it was possible to obtain longitudinal radial sections at least two inches long from material taken straight out of the preserving fluid. These sections provided excellent material for the study of the changes that are occurring below the exposed surface.

GENERAL OBSERVATIONS ON THE HEALING SURFACE.

When any branch end which has developed a block is split open in a longitudinal direction, the position of maximum blocking can be distinguished as a deep-brown to black-green mark situated about five-eighths of an inch below the cut surface. This region of maximum blocking separates the dead outer tissues from the inner living ones. In the cortical region the blocking occurs very near to the cut surface, but it occurs much more deeply seated at the centre of the stem. In the material so far examined it is an invariable rule that the pith becomes blocked relatively early, such pith block being always comparatively deep seated. In some cases oblique cuts were made and it was found in these cases that the position of maximum blocking was always nearer to the surface and was more extensive. This is doubtless due to the fact that with an oblique cut the relative number of living cells to woody tracheæ exposed, is increased. The younger woody tissues are more efficient in producing blocking than are the older ones composed mainly of vessels and tracheids. When a wound is made close to a living branch the blocking is governed by its emergence. These points are illustrated in text figs. 1-4 (page 101). The observations so far seem only to endorse the practice of making oblique cuts in close proximity to living branches.

It might have been expected that most of the exposed branch ends would have been invaded by micro-organisms of various sorts, but as a matter of fact fungus invasion was the exception rather than the rule, particularly in sycamore and rhododendron. The apple and plum stems, however, were rather more frequently attacked. In no case have these fungus hyphæ been seen to penetrate beyond a blocked region ; they always stop just short of it. It must be insisted however, that careful observation has failed to reveal the presence of fungus hyphæ in many of the stems examined, also that the blocking here recorded often precedes fungus invasion and is quite independent of it. It is a purely normal physiological response to the severing of a branch end. Where the process of plugging is complicated by the presence of micro-organisms the formation of this gummy substance may in some measure be associated with them, but the copious gum formation described in this paper which results in the blocking of the xylem tissues, can be and often is quite independent of fungus invasion. It seems probable that a fungus invasion can induce this gum

formation ; this is doubtless because it kills the immediate invaded tissues. The significant fact is that in these latter cases the gum formation is always just beyond the invaded region, i.e., at the junction of the dead and the living tissues. This is precisely its relative position in those wounds under study in this paper



FIGS. 1-4.—TO ILLUSTRATE POSITION OF MAXIMUM PLUGGING.

and it seems clear that this gum formation is in some way connected with the effect of a dead or dying cells upon the metabolism of the tissues in proximity to them. The results of the microscopical study of the natural process involved in the isolation of dead and decaying tissues from living ones must now be presented.

HISTOLOGY OF HEALING SURFACE.

The response to wounding is governed by the time of the year in which the wound is made; the responses fall into three groups, the months giving similar responses are grouped together and considered as a series.

A Series.

Into this series fall the wounds made in late May, June, July and August, that is during the period of active growth and of most active sap movement within the tissues. When a normal 4-6 year old stem is examined in any of the above months the medullary ray cells, and those cells bordering upon the xylem vessels are found to be more or less full of starch grains. In this series, within ten days of wounding, the starch begins to disappear from the region extending from an eighth to five eighths of an inch below the cut surface, and disappears completely from this region in from two to four weeks after wounding. The few cells immediately on the exposed surface invariably retain their starch content even after eighteen months' exposure. Further evidence of some changed conditions in the region of starch disappearance is afforded by the observation that the medullary ray cell walls stain more intensely with iodine or methylene blue than they do in any other part of the section.

The disappearance of starch is followed almost immediately by the appearance in these cells of two characteristic substances. The first is a pale yellow viscous substance; the second, colourless, highly refractive globules of varying size. They seldom occur together in the same cell, the former being most abundant in younger wood and phlœm, the latter being almost restricted to the older tissues, particularly the medullary ray cells bordering upon the pith. It has not yet been found possible to identify these substances although some of their reactions are given. When the viscous yellow substance first appears it either remains unstained with methylene blue or stains green; it is not stained by ruthenium red (pectin stain), Sudan III., or iodine, nor does it give any reaction for tannin. It is insoluble in ether, alcohol, alcoholic hydrochloric acid, alcoholic potassium hydroxide, and Schweitzer's reagent; it is digested with difficulty by cold Eau de Javelle, but much more readily by hot Eau de Javelle or cold Schultze's macerating fluid. (Potassium chlorate in concentrated nitric acid.)

The globules are equally devoid of characteristic micro-chemical reactions. They are insoluble in alcohol, very slightly soluble in ether, chloroform, alcoholic hydrochloric acid, alcoholic potassium hydroxide (hot or cold), and Schweitzer's reagent; also insoluble in hot or cold water, cold Eau de Javelle and a solution of one per cent. tannic acid. They are readily digested in Schultz's macerating fluid, and a considerable number of them, particularly the smaller ones, are

digested by hot Eau de Javelle. They frequently stain light blue with methylene blue, are not stained by ruthenium red or iodine ; they also stain slightly with congo red, and give a slight xanthoproteic reaction. (Concentrated nitric acid is added to the sections, then neutralised by adding ammonia. Substances containing a tyrosine complex give an orange red colouration). They stain black grey with osmic acid, and stain brown with Sudan III. After the month of May the globules give positive reactions for tannin. (Haas and Hill, *loc. cit.*, p. 196). Heating with an alkaline solution invariably turns them brown. Sections containing many of these globules were immersed for a period of three months in a saturated aqueous solution of copper-acetate, other sections similarly treated, were in addition boiled in the solution twice every week. At the end of the period the globules were still colourless. Had they been true resins they would have been coloured light green to dark blue by this process, the only characteristic test that we have for resins.

The development of the viscous substance is followed almost at once by the appearance of a similar substance in the lumen of the vessels. This first accumulates as small blocks of a characteristic shape uniformly distributed over the starchless zone, but within a month localised larger masses are found plugging up the vessels and tracheids. This gummy substance in the vessels soon begins to contract in volume and to turn dark brown in colour. This colour change is accompanied by an increasing resistance to the action of Eau de Javelle and after about five weeks this substance is extremely resistant even to prolonged treatment with Schultze's macerating fluid. A still further indication of change is given by the fact that along with this colour change and increasing resistance, the masses develop the property of giving all the lignin tests and an intense tannin reaction.

Such changes in staining reaction may probably go a long way towards explaining the experience of other workers (3 and 7) which have been confirmed during these observations that the viscous blocking substance does not stain equally, but various parts show considerable differences in the intensity of certain staining reactions.

Thus, if a branch be severed in May, June, July or August, the exposed end will become plugged in about ten days, and completely blocked in about four or five weeks. Throughout the following winter there is no apparent change in the block or the living tissues situated immediately below it, but in late April and throughout May there is evidence of considerable physiological activity just below the block. The middle lamellæ of the medullary ray cells below the block become swollen, the pectin being forced out through the pits in the cell walls so that it appears as small beads at the surface of the pits. Translocation of pectin has not been observed though the blocks develop an intense pectin stain about this time, which at least suggests that some of the pectin has been

carried up to them by the ascending sap. Such pectin disintegration does not occur above the block. Serial transverse sections have indicated that this enlargement of the middle lamellæ begins first in those cells bordering upon the xylem vessels, but later spreads to the medullary ray cell walls where it is then most pronounced. The middle lamellæ do not disappear entirely, but in many cases remain as highly refractive lines which fail to give any pectin reaction. So far it appears that this pectic disintegration is a transitory phenomenon occurring in a limited area below a functional block during late April and early May.

In those summer months immediately following wounding and blocking there is a small but appreciable accumulation of fatty substances in the cells of the starchless region below the block. In the following spring however the accumulation is very abundant, particularly in those cells which have not developed much of the viscous substance within them.

Briefly then, in this series starch rapidly begins to disappear whenever a branch end is cut off. This is followed by the development in the cells of a viscous substance which presumably passes out into the vessels, thus blocking them up. This substance once it is in the vessels changes colour, becomes very hard and resistant, and develops certain staining reactions which it did not previously possess. Throughout winter there is no change, but in the following Spring the middle lamellæ of those cells adjoining the block on the lower side become swollen and are partially disintegrated. There is also a well-marked accumulation of fatty substances in the starch free cells below the block. The evidence suggests that the causal factors are in some way linked up with the substances moving in the xylem sap, and it may be noted that all these changes namely starch disappearance, gum formation, pectic disintegration, and fat accumulation occur in sequence in those cells which in normal wood are living starch containing cells.

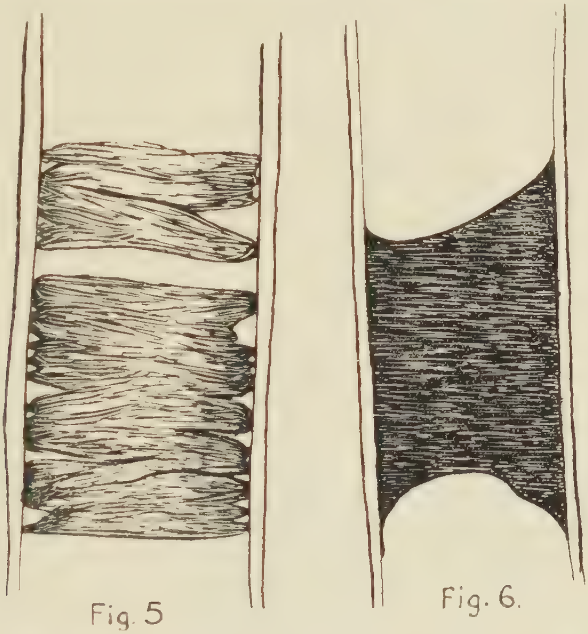
B Series.

In this series are the wounds made in September and October. After wounding a considerable but not complete starch disappearance takes place. There is relatively little of the viscous substance developed in the medullary ray cells and very little appears in the vessels. Those gum masses which do develop in vessels are always more or less evenly scattered over the region of starch disappearance, tend to be square in outline, are often wrinkled and are partially contracted from the walls of the vessels. They thus form a contrast to the plastic homogeneous concave ended blocks of the A series previously described. The two types are illustrated in text figures 5 and 6 respectively (page 105).

The conducting elements in this series are, as the result of this poor gum development, only partially plugged and they remain in this state throughout

winter. In the following May starch disappearance becomes complete, copious gum development ensues and the conducting tissues become blocked. Considerable pectic disintegration similar in all respects to that already described in the A series takes place, the blocks passing through similar stages of development to those recorded for this series.

Throughout the whole of this work it has been noticed that the younger woody tissues are by far the most reactive, gum formation in them being very copious. This greater power of response on the part of the younger wood may in some measure help to an understanding of the property which young fruit



FIGS. 5 AND 6.—TO ILLUSTRATE THE "SQUARE" AND "CONCAVE" BLOCKS RESPECTIVELY.

trees exhibit in particular of recovering from attacks of parasitic organisms which are invariably fatal to the older trees. It is highly probable that the younger trees succeed in isolating the fungus by developing a copious gum barrier.

C. SERIES.

This contains the wounds made in November, December, January, February, March and April, that is during the dormant season. Except in the April wounds which approach towards the A series, there is a negligible amount of starch disappearance. A few isolated square blocks develop at randon, but no plugging of the vessels takes place until early the following May, when the whole series undergoes simultaneously the following development. Starch begins to disappear, gummy substances develop and blocking is complete in about four to six weeks from the beginning of starch disappearance.

The gummy substance is of the same nature as that of both preceding series. The intensity of the pectic disintegration of the middle lamellæ is greater in this series than in the two previous ones, and has been observed to occur before there is an effective plugging of the vessels, while the area exhibiting this phenomenon is also greater in this series than in either of the other two. This is probably to be accounted for by the fact that the vessels have remained open all winter and hence are partially decayed, and the tissues less resistant to the action of the enzymes brought up by the rising sap (16 and 22). The subsequent development of the lignin reactions in the blocks and the accumulation of fatty substances is in all points similar to that recorded in the A and B series.

EXPERIMENTAL DETERMINATION OF THE EXTENT TO WHICH CUT SURFACE IS BLOCKED.

Boehm (4) has previously reported upon the impermeability of wound gum impregnated tissues, and these observations were confirmed and extended by the following experimental method. Pieces of branches three to four inches long, one end being the exposed end, were taken and inserted separately through rubber stoppers and fastened securely into the neck of a large filter flask. The whole was then inverted and the lower end immersed in a bath of safranin dye (1 % in 70 % alcohol.)

The filter flask was then exhausted by means of a filter pump fitted with a manometer (see text fig. 7 page 107). Branches cut in every month of the year and alter healing for varying lengths of time were thus treated. Considering the wounds made during the months May to August, i.e., the A series above, it was found that a month after wounding it was almost impossible to draw any dye through the tissues, while two months after cutting, a reduced pressure of 70 mm. of mercury applied continuously for thirty-six hours failed to draw dye more than a few millimetres into the tissues. The wounds made in September and October, i.e. the B series above, developed a small resistance to the passage of dye in a month to six weeks after wounding, but remained in this more or less open state all throughout winter. The wounds made from November to March remained as easily penetrated by dye as a piece of normal branch, the dye passing up the whole length of the piece used in this experiment, within two or three minutes. The xylem tissues of the B and C series remain therefore in an unblocked state all winter until the following May, when there is a marked increase in the resistance to dye penetration, so that by the beginning of June all the wounds of both series are effectively blocked. It is evident that these results are in accordance with those obtained by histological methods of study, and the general principle emerges that effective and comparatively rapid blocking of the

vascular tissue takes place only during the months of active growth, that is from May to August. Wounds made at any other time are effectively blocked when the sap is rising in the following spring.

DISCUSSION.

The histological evidence briefly presented in a previous section of this paper makes it clear that the main agency in effectively blocking the exposed

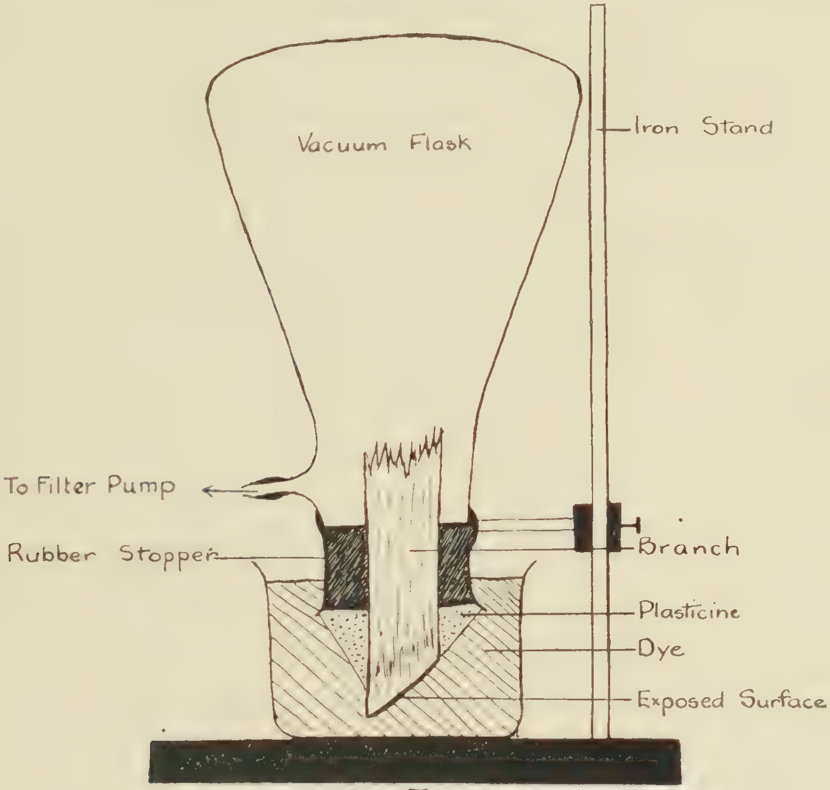


FIG. 7.—TO ILLUSTRATE METHOD OF TESTING THE AMOUNT OF PLUGGING.

surface of a cut woody stem is the viscous substance which, forming first within the living, normally starch containing, parenchyma of the wood and medullary rays, spreads later to the dead tracheæ which it finally plugs.

The chemical nature of this substance is not clear, but provided that the term " gum " is not used with any definite chemical connotation little harm is done by describing it as " Wound Gum." Undoubtedly this viscous substance, which hardens and contracts with age when a cut curface is exposed to air, is the wound gum of most authors who have written about wound healing. If, however the solubility of this substance is considered, it is clear that it has no right to an

inclusion in the category of gums as defined for instance in Haas and Hill (*loc. cit.*, 1921, page 142).

Initially this substance, as it appears in the living cell or the dead tracheæ, may be of the nature of a true gum, its reaction with methylene blue at this stage suggests that it is acidic in nature. It seems advisable at this point to insist upon the difference laid down by Fawcett (6) between the soft brown gum exuded on to the surface of certain species of trees, notably Prunus and Citrus when they are attacked by certain disease organisms, and the hard dark brown substance which is found impregnating the xylem tissues in the vicinity of wounds on the same trees. Higgins (7) gives a wide range of plants in which the latter phenomena has been observed. It is probable that the two substances are initially the same, but whereas the gum which remains in the xylem elements undergoes lignification, this fails to occur in that which is exuded at the surface of the bark. Fawcett (6) also records the development of lignin reactions in the gum remaining in the vessels some time after it has been formed. This fact may go far towards explaining the peculiar grades of staining intensity exhibited by the gum masses in the vessels, and wound gum generally. The two types of gums recorded by Brooks and Storey (3) as occurring in plum wood attacked by Silver-leaf Disease can also be similarly interpreted.

The globules remaining in the living cells near the cut surface and which were particularly described in the account of the histology of the A series must provisionally be distinguished from the viscous substance thus identified with wound gum. These globules are again singularly negative in their micro-chemical characterisation and although they fail to give the only characteristic micro-chemical reaction for resin, there seems little doubt that these substances have occasionally been referred to as resins, or resinous substances. It will be noted that they are specially associated with the pith and inner woody tissues and Coster (5) points out that such resinous substances also appear in the changes involved in the formation of heart-wood.

One point seems clear from the mode of appearance of both viscous substance and resinous globules. They may both be causally connected with the disappearance of starch from the medullary ray cells and wood parenchyma (and, in the case especially of the resinous globules from the pith). This, of course does not exclude the possibility of other compounds, particularly pectins from the walls, contributing to their formation.

In the case of wound gum this conclusion is in complete agreement with that of Coster in his study on heart-wood formation in *Tectona grandis*, in which he decides that wood gum is formed by the conversion of starch into a more resistant substance or mixture of substances. There can also be little doubt that his experiments as to the conditions of formation of this substance in the

case of a tropical heartwood, or in wounded branches, will apply to European trees. His experiments upon gum formation in the presence of anæsthetics and under various conditions, indicate that its formation from starch depends upon enzyme action under suitable conditions, but these necessary conditions do not include access of oxygen or that the cell containing the starch should be still alive.

As the starch-containing cells in the wood die, their contents may become accessible to the activity of enzymes in the sap circulating in the wood, and it is not without significance that the rapid disappearance of starch in the neighbourhood of the wound, and the appearance in its place of relatively large quantitites of wound gum only takes place in those months of the Spring and Summer in which sap is rising in the trees. Sycamore is a tree from which, in the Spring, sap can be obtained if the branches are cut.

In the Spring of 1924 and 1925 Sycamore sap was collected under aseptic conditions and an examination made for certain enzymes. In 1924 sap began to drop from cut branches on March 4th (16). In this sap, as well as that collected from the same trees later in the same month and again on several occasions in the Spring of 1925, 1.3—1.5 per cent. of cane sugar was found and suitable tests showed the following enzyme activities.

Oxidase	a very slight action.
Peroxidase	very vigorous.
Catalase	very faint.
Invertase	marked action.
Diastase	marked action.
Lipase	marked action.

All tests for pectase or pectinase were negative.

Recent work in this laboratory (17 and 19) has shown that in a wounded parenchymatous tissue like the potato the disappearance of starch is accompanied by an accumulation of fatty substances. Similarly in the present investigation there is a considerable accumulation of such substances in the starchless cells below the block. This is even more marked in the rhododendron, as is shown by the following experiment in which every two days the degree of starch disappearance from wounded rhododendron stems was noticed. On the afternoon of the 15th of September, 1923, a number of stems were suitably wounded by cutting off the ends of the branches.

Control Stems.	Starch evenly and abundantly distributed throughout the parenchymatous cells
Stem 2 days after wounding ..	No change.
Stem 4 days after wounding ..	Slight disappearance of starch.

Stem 6 days after wounding ..	Starch perceptibly less in the region extending from $\frac{1}{8}$ to $\frac{1}{4}$ inch below cut surface.
Stem 8 days after wounding ..	Loss of starch slightly more pronounced than in 6 days stem.
Stem 10 days after wounding ..	Starch almost gone from the region extending from $\frac{1}{8}$ to $\frac{3}{8}$ inch below cut surface and an appreciable fat accumulation in the starchless cells.

Rhododendron is a peat-loving plant. Other work done in this laboratory (8 and 9) has shown that many of the plants of a peat habitat have a characteristic habit of forming copious quantities of fats as bye products of their metabolic activity, but the general occurrence of fatty substances in living tissues below a wound, and their apparent formation at the expense of carbohydrate reserve substances seems a wide spread phenomenon. As the proportion of the area covered by living cells just below the cut surface is much smaller in a woody tissue than in a parenchymatous one such as is exposed in a cortical wound or in a cut potato tuber, it is readily understood that the loss of fatty substances from these living cells at the exposed surface of a woody shoot fails to give rise to a continuous layer of oxidised fatty material of a suberin like nature. Thus the significant biological feature reported as the first stage of the healing of an exposed parenchymatous surface is not repeated in the case of a woody stem. The continuous layer of suberin near the parenchymatous surface is laid down in a continuous mass of living cells and leads as a rule to the early formation in these cells of a phellogen giving rise to cork. The suberin layer failing in the first place, and secondly the continuous layer of living cells being absent, no cork phellogen is found below the blocked surface in the woody stem, except in the region of the cortex and outer secondary bast, or occasionally in the pith if this is still an active parenchymatous tissue. It is only when, as the result of a much later covering of the healed surface by a continuous layer of living cells as a result of the renewed activity of the cambium, that a phellogen appears near the outer region of this callus and gives rise to a typical cork layer.

The evidence advanced in this paper to show that effective blocking of the xylem tissues at an exposed surface only takes place during the late Spring and Summer months, is extremely relevant to the problems connected with the entry of wound parasites and is strongly in favour of the practice of summer as against winter pruning. Recently two unpublished observations bearing upon this question have been communicated to the writer. Dr. H. R Briton-Jones, Mycologist at the Research Station, Long Ashton, Bristol, has observed that " the longer in spring that winter pruning can be delayed the fewer will be the

number of attacks by wound parasites." Prof. H. B. Fawcett, Mycologist, University of California, says: "It has been my observation for a number of years that if large limbs of Walnut or Citrus trees are cut out during the growing season the wounds are much more likely to heal up without being infected with wood rotting fungi than if this same kind of pruning of large limbs is done in the fall or Winter."

The ability of disease organisms to penetrate through the blocked xylem tissues is a question of considerable importance. Observations of a considerable number of such exposed branch ends suggest that they are not able to penetrate it, particularly when active callus formation has begun. Where trees are felled so close to the ground that no callous formation occurs it is of course another matter, but where new growth ensues there are rarely any signs of disease organisms having gained an entry. It is presumed that this is due to their inability to penetrate the gummy block. Brooks and Storey (3) record certain cases, particularly in pear trees, of recovery from attacks of Silver-leaf. In such cases the disease fungus has apparently been isolated within a limited area of invaded wood by the impregnation of the surrounding xylem tissue with substances of a "wound gum" nature. In this case at least the wound gum was able to act as a complete barrier to the further development of the fungus.

Finally, the bearing of the present work upon Silver-leaf disease remains to be emphasised. Brooks (1) has indicated that the months June, July or August remain almost free from attacks of this disease. This period it will be noticed corresponds to the A series above. It seems, therefore, that during these months the normal physiological response to wounding is so vigorous that the entry of disease micro-organisms is almost if not entirely prevented, and that these months will ultimately prove to be the best ones in which to make wounds of any sort in woody stems, at least as far as the natural process of closing the wound is concerned.

SUMMARY.

The histology of the early stages of the process of natural healing have been followed in woody stems cut in every month of the year and left to heal for periods of one, two, to twelve months.

As a result, such wounds can be grouped into three series in reference to their general manner of healing, viz.:

A. Wounds made in May to August inclusive.

B. Wounds made in September and October.

C. Wounds made in November to April inclusive.

Wounds of the A type rapidly block against the entry of disease organisms; B series block only partially, and C series hardly at all, until the following spring when they are rapidly and completely blocked.

The progress of blocking can be tested experimentally by trying to suck a coloured dye across the healing stump. The process has been followed under the microscope and mainly consists in the gradual plugging up of the dead tracheæ by a deposit of a viscous substance in them, "wound gum." This substance is of unknown chemical nature; its formation is causally connected with the disappearance of starch from parenchyma cells in the neighbourhood of the wound; it is probably of an acidic nature, and possibly a true gum when first formed, but in an exposed wounded surface it changes continually in nature and in micro-chemical reactions, these changes being different in nature when they occur under different seasonal conditions.

The experimental results would appear to favour the practice of Spring and Summer pruning so far as the natural closure of the cut surface against the entry of disease is concerned.

I wish to take this opportunity of acknowledging the receipt of a small grant from the Ministry of Agriculture to cover travelling expenses in connection with this work; and during part of the time I held a Research Scholarship also awarded by the Ministry of Agriculture. My best thanks are due to Professor J. H. Priestley, Department of Botany, University, Leeds, at whose initiative and under whose supervision this work has been carried out, for his valuable criticism and suggestions, but particularly for his help in presenting the results in their present form.

My thanks are also due to Professor B. T. P. Barker, Long Ashton Research Station. Under Professor Barker's supervision the experimental results outlined in the above paper are being applied to some of the practical problems of Pomology, particularly those of ringing and girdling.

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Explanation of Plate Figures.

1. Longitudinal tangential section of plum wood taken at position of maximum blocking. Notice the shape of the blocks in the vessels, and that the medullary rays are also blocked.
2. Same section as above showing the junction of the living tissue with the blocked tissue. Note the comparative localisation of the blocked region.

PLATE IV.

FIG. 1.
SECTION SHOWING COMPLETE BLOCKING OF THE XYLEM TISSUE.

FIG. 2.
SECTION SHOWING THE LOCALISATION OF THE BLOCKING.

INVESTIGATIONS ON CHLOROSIS OF FRUIT TREES.

I.—THE COMPOSITION OF APPLE LEAVES IN CASES OF LIME-INDUCED CHLOROSIS.

By T. WALLACE and C. E. T. MANN.

Introduction.

The investigations on the chlorosis of fruit trees which are being carried out by the writers have been undertaken as a section of their studies on the wider problem of "The Nutrition of Fruit Trees."

The scope of the investigations is limited to the study of so-called accidental chlorosis—that is, to chlorosis in trees which normally are not chlorotic, in which the chlorotic condition is the result of environmental factors such as particular soil conditions.

The work up to the present has proceeded along three main lines, viz. :—

1. The occurrence of chlorosis in relation to soil conditions.
2. Chemical investigations on the foliage of chlorotic trees.
3. Experiments with a view to the control of the condition in the field.

In this communication it is proposed to present certain results which have been obtained in 2.

The results of our investigations under 1. and 3. will be dealt with fully in later papers as although some very definite progress has been made, further data are required to permit of definite conclusions being drawn.

In this paper, in presenting the results obtained on the composition of apple foliage, it will be necessary however to present certain soil data and to refer to certain experimental treatments in order to show clearly the conditions with which chlorosis was associated in the particular cases under consideration and to indicate the treatments by which green foliage was produced in other cases on trees which had previously been chlorotic.

The foliage which has been examined was obtained from apple trees growing at five different centres. These centres were selected from a fairly large number which have been under observation as providing suitable material for the work.

Soils of the Chlorosis Centres.

In Table I. are given details relating to the Geological Formations from which the soils are derived and to the amounts of carbonates—calcium carbonate, except at Centre A.—contained in the soils at various depths.

TABLE I.

Soil Data from Chlorosis Centres.

Centre.	Surface or Subsoil, etc.	Geological Formation.	Total Carbonates in air-dried soil (reckoned as $CaCO_3$) %
A.	Surface	Dolomitic Conglomerate	25·53
B.	Surface Subsoil 18 ins. to 30 ins.	Keuper Marl " " " "	11.86 19·92 19·58
B.	Surface Subsoil	Keuper Marl " "	6.08 3·77
C.	Surface Subsoil	Lower Lias " "	14.85 9.92
D.	Surface	Chalk	69.0
E.	Surface	Inferior Oolite	18.40

It will be noted in the table that all the soils contain high percentages of carbonates, which is the soil feature usually associated with chlorosis—though other soil features are found to be associated with the condition(4.5)—and so far as we are aware by far the most common feature associated with chlorosis of trees in this country. Indeed, our soil investigations have led us to the conclusion that there is a large element of risk attaching to the planting of fruit trees on either chalk or certain of the limestone formations in this country as although the quality of the fruit from such plantations is almost invariably excellent the trees generally succumb prematurely to chlorosis and in certain cases fail entirely to become established. At the centres considered in this paper the trees have failed conspicuously and it has been obvious that the soil conditions are quite unsuited for the growing of trees under the cultural methods usually followed in fruit plantations.

From certain results which we have obtained in our experimental treatments of the trees, it appears that it will be possible to grow trees free from chlorosis on certain of these soils by the use of special methods.

The following notes are included to supplement the data presented in Table I. :—

Centre A. The Geological Formation from which this soil is derived is not generally utilised for commercial fruit growing. The formation is fairly extensively developed in Somerset and the soil generally exerts a marked toxic

action on trees which invariably show symptoms of chlorosis. Cases of chlorosis on this formation have been discussed in a previous paper by one of us.(6)

The underlying rock at this centre is Dolomitic in character and the soil is generally shallow and stony, the stones consisting of pieces of Dolomitic limestone. The surface soil sample taken for analysis contained 34.6 per cent. of these stones.

Centre B. The amount of carbonate found in the soil at this centre varies greatly over quite small areas as it is derived from small bands of limestone known locally as "skerry." It was shown by sampling that only the trees in the vicinity of these outcrops developed chlorosis. Thus, in certain areas of the plantations the carbonate content in successive 9 inch samples from the surface down to 27 inches depth was of the order of 0.1 per cent., whilst at other points near the outcrop the amounts shown in the table were found. Up to the time when the plantations were first visited, on the former of these areas and on the area for which the data are presented in Table I. in which the carbonate content of the surface soil was 6.08 per cent., the trees had made excellent growth and were entirely free from chlorosis. During the same period the trees on the area showing 11.86 per cent. of carbonate in the surface soil were severely chlorotic and had failed to make healthy growth.

Centre C. The carbonate content of the soil at this centre is variable in patches depending on the proximity to the surface of bands of lias limestone which underlie the clay soil. In addition to the naturally occurring carbonate, the amount in the surface soil has been considerably augmented by the applicaton of dressings of lime.

Centre D. This soil is a thin bare chalk soil, the underlying chalk rock often occurring at a depth of 9 inches.

Centre E. The soil is a typical brashy oolite soil, containing a large percentage of oolitic "stones" and having the underlying limestone rock at depths varying from a few inches.

The data provided in Table I. together with the foregoing notes will suffice to show that the cases of chlorosis considered are typical cases of so-called lime-induced chlorosis in which the occurrence of the chlorotic condition is associated with high contents of carbonates in the soil.

FOLIAGE DATA.

The analytical data obtained on the foliage are reported in Table II., and the following notes on the samples are added in elaboration of these to show the sources of and the particular circumstances under which the samples were collected.

TABLE II.

Results of Analyses of Leaf Samples of Apple from Chlorosis Centres.

Sample No.	A.	A.1.	A.2.	A.3.	A.4.	A.5.	B.	B.1.
Variety.	Wellington	Wellington	Wellington	Wellington	Wellington	Wellington	Lane's Prince Albert	Lane's Prince Albert
Condition of Leaves.	Green.	Chlorotic.	Green.	Chlorotic.	Green.	Chlorotic.	Green.	Chlorotic.
Date of taking Samples.	27/7/23	27/7/23	9/7/25	9/7/25	4/9/25	4/9/25	24/7/24	24/7/24
	%	%	%	%	%	%	%	%
Dry Matter	—	—	34.59	29.65	37.43	32.94	—	—
Ash in Dry Matter ..	9.47	12.60	10.87	11.69	9.74	9.12	9.76	13.40
Fe_2O_3 in Ash	—	—	1.17	0.62	0.33	0.12	0.34	0.59
Al_2O_3 ,, ...	—	—	1.22	1.39	0.05	0.34	—	—
CaO ,, ...	31.60	20.42	35.51	22.54	28.65	16.27	30.72	13.27
MgO ,, ...	3.89	4.48	7.00	5.95	5.15	4.45	6.59	5.97
K_2O ,, ...	30.02	32.57	17.57	28.12	19.64	39.26	16.32	39.11
Na_2O ,, ...	—	—	—	—	9.29	13.35	—	—
SiO_2 ,, ...	0.29	0.32	0.98	2.60	2.71	4.61	—	—
P_2O_5 ,, ...	3.57	4.49	3.57	3.76	2.17	3.72	4.99	4.67

Sample No.	B.2.	B.3.	B.4.	B.5.	C.	C.1.	C.2.	C.3.
Variety.	Lane's Prince Albert	Lane's Prince Albert.	Lord Grosvenor.	Lord Grosvenor.	Monarch.	Monarch.	Monarch.	Monarch.
Condition of Leaves.	Green (Shoot leaves).	Green (Spur leaves).	Green.	Chlorotic.	Green.	Chlorotic.	Green.	Chlorotic.
Date of taking Samples.	22/9/25	22/9/25	22/9/25	22/9/25	13/6/25	13/6/25	4/9/25	4/9/25
	%	%	%	%	%	%	%	%
Dry Matter	38.46	39.60	39.09	31.71	31.92	23.86	38.18	27.92
Ash in Dry Matter	8.62	9.98	9.68	11.59	7.90	9.49	9.18	11.96
Fe_2O_3 in Ash	0.15	0.02	0.15	0.26	0.69	0.59	1.07	0.04
Al_2O_3 ,, ...	0.10	0.11	0.29	0.09	—	—	0.09	0.07
CaO ,, ...	29.90	28.50	23.83	14.04	11.92	5.86	22.75	14.53
MgO ,, ...	8.47	7.12	8.99	5.65	5.50	5.25	5.55	5.40
K_2O ,, ...	17.07	11.19	17.14	34.91	28.05	44.66	22.67	40.89
Na_2O ,, ...	22.85	22.42	17.46	20.21	—	—	8.09	12.60
SiO_2 ,, ...	4.66	5.75	2.63	1.59	1.51	2.77	3.21	3.02
P_2O_5 ,, ...	3.55	3.55	3.80	4.95	8.54	9.85	3.02	4.47

Sample No. Variety. Condition of Leaves. Date of taking Samples.	D. Worcester Pearmain. Green. 6/6/25	D.1. Worcester Pearmain. Chlorotic. 6/6/25	E. Lane's Prince Albert. Green 4/9/25	E.1. Lane's Prince Albert. Chlorotic. 4/9/25
	%	%	%	%
Dry Matter	32.83	28.46	39.95	38.06
Ash in Dry Matter ..	7.41	10.70	10.72	13.64
Fe_2O_3 in Ash	0.64	0.49	0.19	0.14
Al_2O_3 ,, ...	—	—	0.17	0.19
CaO ,, ...	15.40	7.02	32.13	24.98
MgO ,, ...	4.19	6.57	6.25	4.70
K_2O ,, ...	35.24	44.08	14.34	—
Na_2O ,, ...	—	—	9.79	—
SiO_2 ,, ...	2.28	3.17	2.76	3.45
P_2O_5 ,, ...	10.84	9.20	3.91	4.31

Samples A.—A.5.

Samples A.—A.5 were all taken from the same tree, which was growing in a garden under good cultural conditions and which had received generous manurial treatment. In 1925, it was about twelve years of age and had shown symptoms of chlorosis for several years. During the seasons of 1923 and 1924 practically the whole of the foliage was markedly chlorotic and in the latter season the fruits borne had the appearance of wax models and were without any trace of green colour. A portion of the foliage was sprayed with a solution of sulphate of iron in 1924 and the spraying was repeated over the whole of the foliage in June, 1925, following which it was exceedingly difficult to obtain samples of chlorotic leaves from the tree on the two dates given in the table—July 9th and September 4th.

Samples B.—B.5.

Samples B. and B.1 were taken on the same date, the former from healthy trees about ten years of age growing on an area as shown in Table I. where the surface soil contained 6.08 per cent. of carbonate and the latter from strongly chlorotic trees five years of age which had failed to make healthy growth, growing on an area as in Table I. where the surface soil contained 11.86 per cent. of carbonate.

Samples B.2 and B.3 were taken from the same trees as sample B.1 during the following season, during which season the trees were subjected to " grassing down " treatment following which chlorosis was entirely absent and the trees carried normally green foliage and a medium crop of normal fruits.

Samples B.4 and B.5 were from trees of a different variety about ten years of age growing under the same soil conditions as the B.1 trees, clean cultivation being practised.

The tree from which sample B.4 was taken had been sprayed earlier in the season with sulphate of iron solution which had resulted in the partial disappearance of the chlorotic condition whilst the tree from which sample B.5 was taken had been left unsprayed and the foliage had remained strongly chlorotic.

Samples C.—C.3.

Samples C.—C3 were from young three-year old standards growing in a nursery. Samples C. and C.2 were from certain of the trees which had been sprayed with sulphate or iron solution earlier in the season, which treatment had greatly checked the development of chlorosis.

Samples C.1 and C.3 were from control trees which had received no spraying treatment and which were strongly chlorotic, many being in a crippled condition.

Samples D. and D.1.

The trees from which these samples were taken were about seven years of age and were growing side by side in the middle of an area on which the majority of the trees were markedly chlorotic, only occasional trees retaining a proportion of green foliage.

Samples E. and E.1.

The trees from which these samples were taken were four years of age. Those bearing chlorotic foliage had been sprayed earlier in the season with a solution of sulphate of aluminium, which treatment had been ineffective in checking the development of chlorosis. Those bearing the green leaves had not received any special treatment.

In the following discussion the data on certain samples will be compared in order to bring out certain differences obtaining in the composition of green and chlorotic foliage.

In the collection and preparation of samples for analysis every precaution was taken to ensure that the results should allow of comparisons being made. All samples were collected into air-tight tin boxes and were usually in process of analysis within a few hours after picking. Where any delay occurred dry matter percentages were not taken. Prior to analysis all petioles were removed, the data thus referring only to the laminæ of the leaves.

Discussion.

From the data presented in Table II., the following comparisons of green and chlorotic foliage may be made—Samples A. with A.1; A.2 with A.3; A.4 with A.5; B. with B.1; B.1 with B.2 and B.3; B.4 with B.5; C. with C.1; C.2 with C.3; D. with D.1; E. with E.1.

In making these comparisons attention is drawn to the following:

Samples A.—A.5 allow of comparisons between green and chlorotic leaves growing on the same tree in two different seasons and on three different occasions.

Samples B. and B.1 provide data for comparison between green and chlorotic leaves from trees of different ages, growing on the same soil type but with the soils containing different amounts of carbonates.

Samples B.1, B.2, and B.3 allow of comparisons between green and chlorotic leaves from the same trees in different seasons, the green leaves having been developed following " grassing down " treatment. B.1. was a composite sample of leaves from shoot and spur growths.

Samples B.4 and B.5 admit of comparison of green and chlorotic leaves from trees of similar age, the green condition having resulted from sulphate of iron treatment.

Samples C.—C.3 provide data for comparison of green and chlorotic leaves from two batches of trees of similar age on two occasions following the treatment of one batch with sulphate of iron spray which markedly reduced the amount of chlorosis.

Samples D. and D.1 allow of comparison of green and chlorotic leaves from trees growing under soil conditions which appeared to be strongly conducive to chlorosis, which conditions certain of the trees appeared at that time to resist.

Samples E. and E.1 admit of comparison between green and chlorotic leaves from young trees of similar age, growing under similar soil conditions and where spraying with sulphate of aluminium had failed to reduce the amount of chlorosis.

In making the above comparisons four points stand out in very striking fashion.

1. The percentage of dry matter present is in all cases appreciably higher in the green leaves than in the chlorotic leaves.
2. The ash in the dry matter is higher in the chlorotic leaves than in the green leaves in all cases excepting one—A.4 with A.5—in which case the difference is only very small.
3. The percentage of calcium is in all cases markedly lower in the ash of the chlorotic leaves than in that of the green leaves.
4. The percentages of potassium and sodium are always much higher in the ash of the chlorotic leaves than in that of the green leaves; especially is this so in the case of potassium which may show an increase of 100 per cent. in the chlorotic over that of the green leaves in comparable samples.

Other points which require mention are as follows:

1. The percentage of iron, reckoned as Fe_2O_3, contained in the ash of green leaves is not always larger than that of the ash of the chlorotic leaves. The data recorded do not throw much light on this point owing to the complication introduced by the sulphate of iron treatment. Comparison of Fe_2O_3 in Samples B.2 and B.3 shows that very large fluctuations in iron content may occur normally in the ash of green leaves.
2. The data for the amounts of aluminium are not regarded as showing significant differences in either direction owing to the difficulties of estimating this element in samples of ash.
3. The percentages of magnesium are generally higher in the ash of the green leaves than in that of the chlorotic, but there are two cases in which the reverse is the case.
4. The silica content is higher in the ash of chlorotic leaves in six cases and in that of the green leaves in two cases. The former differences are generally large as also is one of the latter.
5. The percentage of phosphorus is higher in the ash of the chlorotic leaves in seven cases and in that of the green leaves in two cases.

The results recorded here for calcium and potassium do not agree with those of several other workers on lime-induced chlorosis whose results are reported by Gile and Carrero(3). These workers have generally found higher percentages of calcium and either similar or lower percentages of potassium in the ash of chlorotic leaves than in that of green leaves. They are, however, similar to those reported by Colin and Grandsire (2) and by Church(1) in carrying out similar studies on congenital chlorosis or albinism. These workers found that the salient points of difference in composition between green and chlorotic leaves of the chestnut, elm and other plants in cases of albinism were the higher dry matter content in the green leaves, the higher ash percentage in the chlorotic leaves, and the higher calcium content and correspondingly lower potassium content of the ash in the green leaves.

SUMMARY.

1. The results of an investigation on the composition of green and chlorotic leaves in some typical cases of lime-induced chlorosis of apple are reported.
2. Soil data are presented to show the nature of the soil conditions which were conducive to the cases of chlorosis considered.
3. Data on the composition of green and chlorotic leaf samples are provided from which it is possible to make comparisons under various conditions.

4. The data show that the salient differences in the composition of green and chlorotic leaves in all cases are as follows :—

   (*a*) Green leaves contain higher percentages of dry matter and lower percentages of ash in the dry matter than do chlorotic leaves.

   (*b*) The calcium content of the ash of the green leaves is much higher than that of chlorotic leaves.

   (*c*) The percentages of potassium and sodium—especially potassium—are much higher in the ash of chlorotic leaves than in that of green leaves.

   (*d*) The differences in the amounts of magnesium, iron, aluminium, phosphorus and silica are not so definite in character as in the cases of calcium, potassium and sodium.

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THE CONTROL OF BIG BUD MITE IN THE FIELD.

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The experimental work on the control of Big Bud Mite on Black Currants in the field, already described in the last Annual Report of the Research Station (1923), has been continued for another year. This study was commenced during the Winter of 1921-1922, on an acre plot of Baldwin Blacks, interplanted between Apple trees and laid out in 1920. The bushes were divided into eight equal plots, of ninety-seven bushes, each comprising a single row of bushes across the plantation at five feet apart, and a short intermediate row at fifteen feet apart standing between the Apple trees. The plots ran north and south, Plot 1 lying to the western extremity and Plot 8 at the eastern extremity. Our observations on the distribution of the Big Buds among the plots show the greater severity with which the series of plots on the eastern half of the plantation have become infected when compared with the plots receiving corresponding treatments on the western half. The most obvious of possible agencies influencing this migration in an easterly direction appears to be the wind. During those months in which migration chiefly occurs, namely April, May and June, our records show that westerly winds predominated over easterly winds by fourteen days in 1921, by thirty days in 1922, by seventeen days in 1923, and by nine days in 1924. While westerly winds predominated consistently throughout the Mays of four years ; two exceptions occurred in April (those of 1923 and 1924), and two in June (those of 1921 and 1924).

During the early Spring of 1922 and of the three subsequent years the plots were treated as follows :—

Plots 1 and 8 all Big Buds hand picked during early Spring.

Plots 2 and 7 sprayed with Lime Sulphur at Winter strength during the Spring.

Plots 3 and 6 odd numbered bushes cut down almost to ground level during one Spring ; even numbered bushes similarly treated next season.

The results of these treatments are compared with those from untreated (control) plots (Plots 4 and 5).

Each treatment is duplicated at opposite extremities of the plantation in order to eliminate as far as possible differences attributable to soil variation or other factors. The planting of the control plots at the centre of the plantation had the obvious advantage of limiting the risk of infection from these untreated bushes to other valuable experimental plantations in the vicinity.

Moreover these control bushes formed an active central source of infection to the treated plots. In this connection, it is worth noting that, although the lime-sulphured plots were nearer to the untreated control plots than the hand-picked plots on the outsides, lime-sulphur spraying gave a larger measure of control than hand-picking. In measuring the full value of lime-sulphur spraying under our conditions this proximity to serious infection should be remembered. Elsewhere, where such sources of infection are absent, we find the measure of control even greater.

DETAILS OF TREATMENTS.

Our hand-picking treatment consisted of removing all obviously enlarged buds during early Spring. It is necessary to stress the fact that this operation, to be most effective, should be performed at as late a date before bud-break as possible, since we have evidence here that the number of enlarged buds increases slightly between, say, November and March. While it is not suggested that the mite could have infected fresh buds during this period, these facts seem to indicate that mites in buds, not apparently enlarged in the early winter, may be capable of causing such enlargement by the following spring.

The lime sulphur spray used was that recommended by Mr. A. H. Lees* (concentration 1 to 12, specific gravity 1.025). While however, Mr. Lees recommended its application when " the leaves are the size of a sixpence ", under our conditions the spray appears more effective if applied at a slightly later date. Thus, in 1922, 1923 and 1924 respectively, the leaves of our Baldwins were on the average the " size of a sixpence," on March 10th, March 14th and April 8th, yet the average date on which we applied the spray in those years was ten days to a fortnight later. We aimed at applying the spray after the flower racemes had appeared, but before the flowers had opened. Although we have not carried out a special series of experiments designed to test the optimum time for this spring spraying, the results of spraying upon our Variety Trial Plots seem to emphasise the value of leaving the operation until the last moment.

Let us compare the measure of our success upon the two whitish ragged budded varieties, Baldwin and Goliath, the former very early in leaf, the latter late. Both these varieties are reputed to be highly susceptible to Big Bud, and, until 1924, they were both sprayed each year on the same day with Lime Sulphur, the Baldwin's being far in advance of the Goliaths.

The control has been much greater on the former, the total number of big buds recorded from the seventy-three bushes of Baldwin being fifteen on eight bushes as against eighty two on fifty two bushes of Goliath. Such evidence is of course only very indirect, since the factors of both variety and location render strict comparison impossible.

* Annual Report, Agricultural and Horticultural Research Station, Long Ashton, 1910.

With regard to the economic aspect of the use of lime sulphur spray, it has been stated that, according to our own figures, this method of mite control is unjustifiably expensive when compared with hand-picking. This idea has doubtless arisen from the fact that the cost of spraying was stated, in error, in one instance, as approximately 4d. per bush. The actual cost of lime sulphur spraying at this Station in the Spring of 1925, using a motor spraying plant, and taking every expense into consideration, worked out at a little less than a penny per bush, or, at 1210 bushes per acre, £4 10s. 9d. Bearing in mind the undoubtedly superior performance of the lime-sulphur spray under our conditions we consider the cost of this operation justified.

The method of cutting the bushes down in alternate years with the object of obtaining fresh supplies of young uninfected wood has several disadvantages. In the first place, only half the bushes are cropping in any one year. In the second place, since the treatment is only applied to half the bushes each year. the control over the spread of mite is only exercised on that half in any one year. The cropping bushes upon the cut down plots in 1923 gave an aggregate crop slightly in excess of the lime sulphured plots, as may be seen from Table 2, though the cropping bushes on these same plots yielded on the average 10 ozs. less fruit per bush than the latter in 1924. So that, in addition to the loss of half the crop in each year as the result of the treatment, there appears to be an actual diminution of crop ultimately, on the bushes so drastically pruned. Again, whilst the treatment must have removed a large percentage of sources of potential infection, buds containing Mite must have remained on the stumps left after cutting down the bushes, since it has been no part of the treatment to hand-pick or lime-sulphur these stumps. It was noticeable on these plots that the majority of the Big Buds which occurred on new growths, in the season following that in which the bushes were cut down, were clustered around the lower half of the shoots.

Measure of Control Attained.

A.—On Healthy Bushes.

The results of actual counts of Big Buds taken during the Winters of 1922, 1923 and 1924, are shown in Table 1. In 1921, before the treatments were applied, each plot had a few Big Buds. The figures in Table 1 are based on the "unreverted" bushes only, even those showing less than the normal number of innervated points in the leaf serration being excluded.* Considerable casualties from reversion occurred in each year, as will be shown later,

* "Reversion of Black Currants, A method of Identification," by A. H. Lees. Journal of Ministry of Agriculture, March, 1921. Referring to such a case, Mr. Lees says, "It has, therefore, a distinct touch of Reversion in its make-up, and any bush having such leaves is suspect."

and our first object was to ascertain how far we could establish control over Big Bud on healthy bushes.

TABLE I.

Showing % of Bushes infected with Big Bud and the severity of attack.

	1921		1922		1923		1924	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Plot 1 Hand-picked ..	2	7	18	27	67	144	96	924
,, 8 ,, ,, ..	5	15	23	97	81	272	100	1758
Both ..	**4**	**11**	**20**	**61**	**74**	**205**	**98**	**1312**
Plot 2 Lime-Sulphur ..	4	10	5	22	48	73	67	172
,, 7 ,, ,, ..	1	3	23	28	76	202	92	404
Both ..	**3**	**7**	**14**	**25**	**62**	**138**	**79**	**282**
Plot 3 Cut Down ..	2	9	20	77	85	414	82	1354
,, 6 ,, ,, ..	5	14	31	123	82	542	95	2089
Both ..	**4**	**12**	**25**	**100**	**83**	**480**	**88**	**1691**
Plot 4 Control ..	4	8	24	125	95	1434	98	5737
,, 5 ,, ..	4	15	30	137	95	1424	100	5929
Both ..	**4**	**12**	**27**	**131**	**95**	**1429**	**99**	**5837**

(a) Percentage of normal bushes infected with mite.

(b) Number of Big Buds per 100 bushes.

Lime-Sulphur spraying at Winter strength has, then, given a very large measure of control under our conditions. While the rate of infection has increased with great rapidity on the other plots, the relative efficiency of the lime sulphur spray in stemming the spread of the mite has increased in each year. Thus, in 1922, 1923 and 1924, the number of Big Buds on the untreated control plots were respectively 5, 10 and 21 times as great as those on the lime sulphured plots. In this connection it is interesting to consider the weather at the time of the application of the spray on these plots. During 1922, it rained on the day on which the spraying was in progress and on four occasions during the ensuing week; in 1923 it did not rain on the day of application, but the following day was wet and it rained on four days during the week immediately following spraying. In 1924, however, the weather was perfectly dry during spraying and for the following ten days. Apart from any diluting or chemical effect which rain may have on the wash, it is fairly certain that its mechanical effect in washing the precipitate from the bushes must militate against the Spray's effectiveness. It is probable that the weather at or about

the time of spraying is an important factor determining the precise amount of control obtained. Hence, it is conceivable that spraying may meet with a different measure of success under different climatic conditions. On the other hand it appears possible that the effects of such a spray are " cumulative " and that the measure of control (over mite infection) obtained increases in each succeeding year.

The effect of the lime-sulphur spray on the mites has been followed out in the Laboratory by Mr. A. M. Massee, and it has been found that the mites are killed by the spray as soon as they commence to migrate from the big buds.

If the big buds are examined under the microscope, a week or more after the application of the spray, dense masses of dead mites will be observed on the surface of the old drying up diseased buds.

Figure A illustrates a typical big bud, sprayed with lime-sulphur, on which masses of dead mites are seen.

Figure B represents one of the big buds taken from a control bush. In this instance mites are seen migrating from the bud in the normal way. These mites would normally re-infect some of the new buds the following Summer.

Hand-picking, which gave promising indications in the early years of the trials, was much less effective in 1924. The most obvious explanation appears to be that the removal of the enlarged buds has not eliminated mite from the bushes entirely, but that mite has remained in unenlarged buds ; on several occasions Mr. A. M. Massee has found this to be the case. It should be recalled that the plots in question are furthest removed from the worst sources of reinfection.

Of the method of cutting down the bushes in alternate years, the best that can be said is that under our conditions a very slight control is obtained. A detailed study of the individual bush records shows that the bushes cut down in one season, after becoming temporarily less severely attacked in the year in which they are forming new shoots, become almost as badly affected as the untreated control plots by the second year.

Effect of Treatments on Cropping.

Throughout the course of the experiments, crop weights of individual bushes were kept. Table II. shows the average crop per " unreverted " bush in each year.

Table II. shows that the cropping of the various plots has been somewhat uneven. The consistently higher cropping of the four most easterly plots again seems to suggest some local advantages. The figures indicate however that the crop has not been seriously diminished by the use of lime-sulphur. The method of cutting down the bushes in alternate years has, on the other hand, resulted in a serious loss of crop in 1924. This is especially interesting

PLATE V.

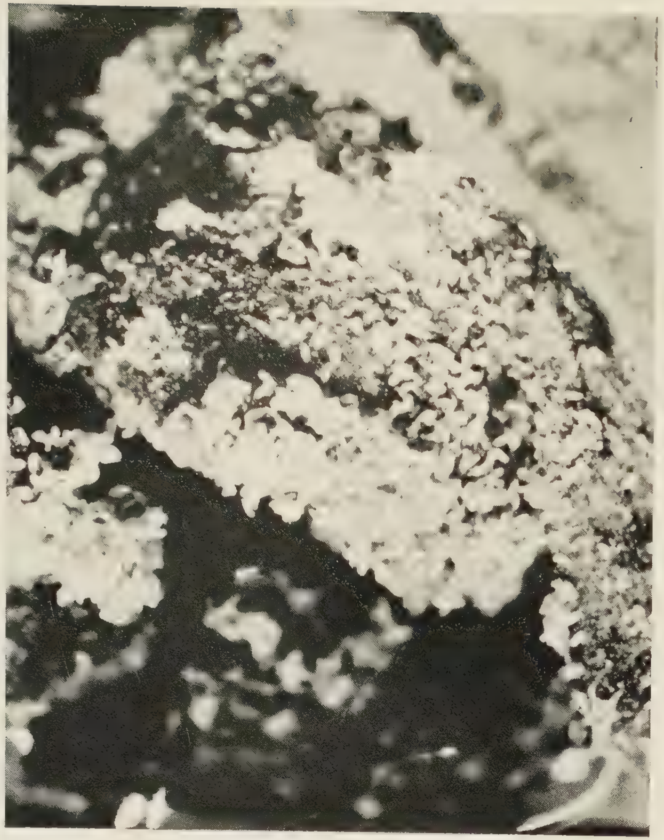

Fig. A.
Black Currant Gall Mites (*Eriophyes ribis* Westw., Nal.) killed by Lime-Sulphur Spray.

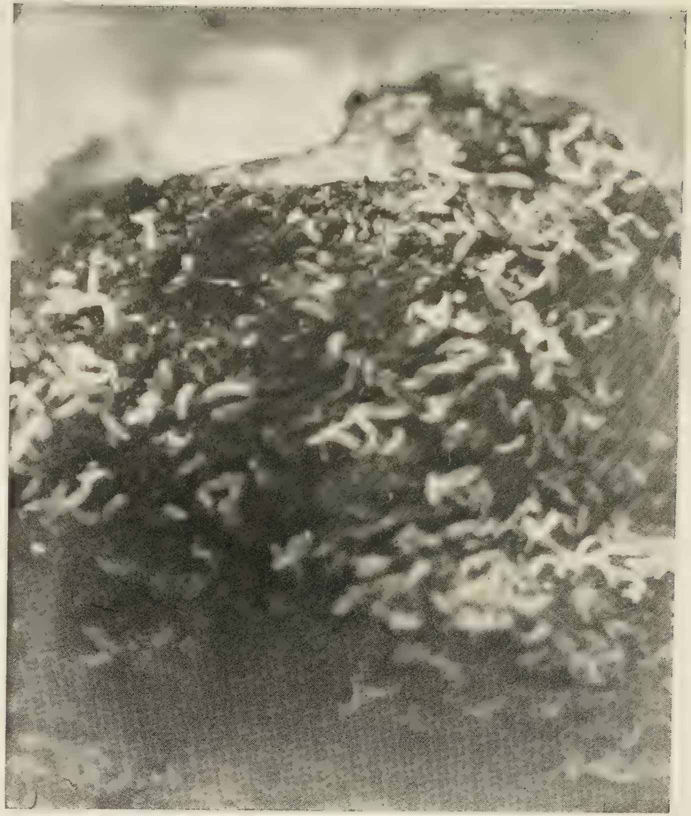

Fig. B.
Black Currant Gall Mites (*Eriophyes ribis* Westw. Nal.) migrating from unsprayed "Big Bud."

when it is remembered that the bushes on the other plots have never been pruned. The "probable errors," worked on the 1924 figures, indicate that the differences between the cropping of the plots are not as significant as they may appear and are probably the result of soil variation or other causes. The only really significant differences are those indicating diminution of crop following cutting down in the previous year. Though the very hard cutting certainly appears to increase fruit size somewhat, it produces growths with very long internodes between the possible fruiting buds.

TABLE II.

Average Crop per Bush in Ounces.

		1922 Ozs.	1923 Ozs.	1924 Ozs.	Average of 3 years. Ozs.
Plot 1	Hand Picked	5·7	41	95	47
8	" "	7·3	59	112	59
Both	" "	6.5	50	103.5	53
Plot 2	Lime-Sulphur	6.2	39	95	47
7	" "	6.6	43	101	50
Both	" "	6.4	41	98	48.5
Plot 3	Cut Down	5.0	43	82	43
6	" "	4.8	44	81	43
Both	" "	4.9	43.5	81.5	43*
Plot 4	Untreated Control	5.9	41	97	48
5	" "	6.1	46	110	54
Both	" "	6.0	43.5	103.5	51

B.—On Reverted Bushes.

Since it is clear that some of the treatments give a good measure of control on healthy bushes, it is worth while to enquire what effect they have on the Big Bud on the "reverted" bushes, more especially as it is well known that Big Bud is apt to spread very rapidly on such bushes. In 1921 and 1922 the reversion was so sporadic that the figures are incapable of interpretation. In 1923 and 1924, however, the Big Bud on definitely "reverted" bushes was appreciably controlled by lime-sulphur; whilst the untreated "reverts" showed 11,575 Big Buds per 100 bushes in 1923 and 8,968 in 1924, the lime-sulphur sprayed bushes showed only 5,225 and 3,150 Big Buds per 100 bushes respectively.

* It must be remembered, in addition, that under this treatment only half the bushes are cropping in any one year.

Effects of Treatments on Spread of "Reversion."

The bushes used in these experiments were obtained from an ordinary commercial source and had been propagated from plantations which we knew contained a considerable percentage of wholly and partially "reverted" bushes. It is therefore more than probable that a number of the young bushes when planted were either already "reverted" or at least infected with "reversion." Hence, it is dangerous to seek any effect of our treatments on the spread of "reversion" until this incipient "reversion" had worked itself out. We have, from other material, evidence that this process often takes at least two seasons. In this connection the actual manifestations of the trouble are of considerable interest. In the first two years (as noted above) "reversion" occurred sporadically in the plots and in nearly every case the affected bushes "reverted" completely in a single season and apparently without any previous attack of Big Bud. In 1923, and still more in 1924, the manifestations became very different; in the great majority of cases the newly "reverted" bushes *had* previously shown Big Bud and the "reversion" itself generally appeared gradually, i.e., on only part of the bush at first. It is, then, perhaps fair to assume that, at any rate by 1924, fresh cases of "reversion" indicated new infections and not the legacy of careless propagation. When we find that just at this period the great majority of the new "reverts" appeared in the untreated and cut down plots, we are surely justified in suggesting that the lime-sulphur spray and the hand picking may have in some way checked the spread of "reversion". Thus, whilst in 1924 the untreated plots showed 18 per cent. of definite new "reverts", the lime-sulphur sprayed plots showed only 4 per cent. and the hand picked plots 5 per cent. The worst of all were the cut down plots, with 23 per cent. This line of observation will become more interesting after yet another season has elapsed.

Summary.

In the light of these field experiments, then, in conditions such as ours we can confidently recommend the spraying of Black Currant bushes with winter strength lime-sulphur wash (1.025 sp.g.) just as the bloom trusses are appearing but before they open. Slight scorching of the very young leaves will almost certainly result but the bushes though temporarily looking yellowish in foliage seem to suffer no ultimate damage. On several occasions the small undeveloped abortive flowers which appear in certain seasons have been mistaken by growers for lime-sulphur damage, but we find these coming just as frequently in the other rows. Microscopical examination of the buds from these lime-sulphured bushes during the migration season has revealed masses of dead mite upon the old Big Buds. Lime-sulphur spraying has become a matter of routine here, even in the cutting beds.

RASPBERRY VARIETIES AND THEIR CROPPING.

By N. H. GRUBB.

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Records of the crops produced by raspberry varieties have been kept at East Malling since 1919. Although only some dozen or more varieties have been planted on such a scale and in such a manner as to satisfy the exacting requirements of modern variety trials (the bulk of the records have been kept on the original rows planted for " roguing " and for raising a supply of planting canes), it seems worth while to present the records as a rough guide to growers of the comparative value of the varieties in our conditions.

The data now available include the complete seven year records for eight varieties, all on 200 to 360 foot lengths of row ; three year records for thirty-two varieties of which some twelve are in rows over 100 feet long ; and two year records for forty-five varieties, in lengths of 50 feet or less. In addition, we have obtained the first crop from some twenty-four more varieties ; but it is not considered worth while to present the figures here.

The eight varieties included in the seven year records have given average crops as shown in Table I.

TABLE I.

Average crop of eight varieties over seven years. Cwts. per acre.

1.	Pyne's Royal	23.9	Best every year except 1919.
2.	Devon	18.0	
3.	Bunyard's Profusion ..	17.2	
4.	Baumforth Seedling B. ..	16.6	Consistently held second place till 1924 and 1925 when severely injured by " anthracnose."
5.	Norwich Wonder.. ..	15.3	Cropped relatively well in 1923 and 1925.
6.	Hornet C.	13.7	
7.	Bath's Perfection ..	12.1	Cropped relatively well in 1919, never since.
8.	Superlative	9.0	Much dwarfed in our conditions.

Of the eight varieties, Pyne's Royal has cropped heavily every year, while Bath's Perfection (with the exception noted) and Superlative have been consistently poor. The other five have varied, and have all been good in some years and poor in others.

It is impossible here to give the complete records of all the varieties which have cropped for three years. Table II. gives the crop of each year separately, for all the varieties which on the average exceeded 1 ton per acre, with a few other varieties of interest. Where more than one sample of a variety is included in the trial, the best is given here.

TABLE II.

Cropping of Raspberries planted in 1921-22. Cwts. per acre.

		1923.	1924.	1925.	Average.
1.	Lloyd George	14.5	67.9	53.5	45.3
2.	Red Cross	12.0	44.6	43.9	33.5
3.	Helston	11.8	39.2	27.7	26.2
4.	Paradise Berry	8.0	46.8	23.5	26.1
5.	Laxton's Bountiful A ..	4.9	37.9	35.0	25.9
6.	Hornet A.	8.6	48.2	20.3	25.7
7.	Baumforth's Seedling A. ..	8.1	40.5	28.1 (die back bad)	24.9
8.	Pyne's Royal	10.7	33.6	29.6	24.6
9.	Reader's Perfection ..	4.9	38.5	29.1	24.2
10.	Black Antwerp A.	9.8	40.1	16.5	22.1
11.	Laxton's Bountiful B. ..	7.1	35.9	22.6	21.9
12.	Mitchells Seedling	6.4	37.5	18.5 (die back very bad)	20.8
12.	Semper Fidelis A. ..	7.4	34.4	20.6	20.8
14.	Red Magnum Bonum ..	13.2	30.1	17.7	20.3
	Baumforth Seedling B. ..	9.9	31.8	14.2 (anthracnose very bad)	18.6
	Priors Prolific	2.2	37.0	12.3 (die back very bad)	17.2
	Norwich Wonder ..	4.8	24.2	22.2	17.0
	Devon	5.7	22.9	20.6	16.4
	Red Antwerp A.	4.3	22.0	13.5 (die back very bad)	13.3
	Bath's Perfection	2.1	17.1	9.4	9.5

It will be seen that in total weight of fruit no other variety has come within a long distance of Lloyd George, except in the first year of cropping. Red Cross is also on the average well ahead of the rest of the varieties, although in 1923 it took third place, and in 1924 fourth. It is worth noting also, that of the five varieties included in both Tables I. and II., Pyne's Royal is again the leader. The other three varieties in Table I. were not replanted in 1922, and thus cannot be included in Table II. The cropping of the one-year older rows of these sorts, however, does not at all suggest that any of them would have been likely to crop as well as Pyne's Royal.

Of the forty-five varieties planted in the winter of 1922-23 very few are standard sorts. Small lots of one or two varieties included in Tables I. and II. were planted, but these do not provide a very satisfactory comparison. The bulk of the varieties were either sorts that have been more or less lost to cultivation, local varieties from various districts, or new sorts (many un-named) which are not yet widely distributed.

Table III. gives the two-year average crop of some of the more interesting of these sorts.

TABLE III.

Two-year average crop of varieties planted in 1922-23. Cwts. per acre.

		Cwts. per Acre.	
1.	North Ward	25.2	
2.	Winklers Seedling	25.0	
3.	Baumforth Seedling B.	24.3	
4.	" Chummies "	20.4	
5.	Norwich Wonder	19.9	
6.	Roosjes (from Holland)	17.6	
7.	Storrie's Invincible (=Norwich W. ?)	15.9	
8.	Laxton's Prolific	15.7	
9.	Superlative ? (from Holland)	15.0	(much more vigorous than our Superlative).
10.	Red Antwerp F. (Barnet ?) ..	14.5	
11.	Wilder (from Holland)	14.3	
12.	Bath's Perfection ? (" Canadian Red ")	13.8	
13.	Hornet A.	13.5	
14.	Baumforth's Seedling A.	12.7	
15.	Brown Hague (from Holland) ..	12.2	
	Hornet E. (" Improved Hornet ") ..	9.5	(very late, part of crop lost).
	Red Antwerp E...	8.6	
	Filby Seedling (=Fastolf ?)	8.0	

Many of the unnamed seedlings cropped extremely well, four of them, in fact, better than any variety in the table. They are omitted because we do not yet know how far the phenomenon of " seedling vigour " is responsible for their early performance. We are quite prepared to find many of them falling off in cropping as they become more mature.

It may be of interest if we show how different samples of the same variety compared in their cropping. Table IV. gives these details for all varieties of which two or more samples were planted in 1921-22 or 1922-23.

The letters following the name of the county in Table IV. indicate definite growers or nurserymen ; samples noted as from Perthshire A. for example, all came from the same farm. It will be noticed that the best cropping samples of Hornet A, Black Antwerp A, and Baumforth B, all come from the same farm in Perthshire.

From the results shown in Table IV. we are strongly inclined to think that the same variety from different sources may have a considerably different value, at least for two or three years following planting. We hope to follow up this point in the near future.

It has already been pointed out that many of the results given in this paper are based on comparatively short lengths of row. A first attempt has now been made to find out what length of row is necessary to give a reliable trial.

TABLE IV.

Cropping of different samples of same variety. Cwts. per acre.

	Planted	Source	1923.	1924.	1925.	Average.
Hornet A.	21–22	Perthshire A.	8.6	48.2	20.3	25.7
,, ...	,,	Kent A1 ..	7.8	34.9	21.7	21.5
,, ...	,,	Cambridgeshire	5.9	34.6	18.5	19.7
,, ...	,,	Kent B. ..	5.7	30.5	19.0	18.4
,, ...	,,	Kent A. ..	5.2	28.9	16.9	17.0
,, ...	22–23	Holland ..	—	10.4	16.7	13.5
Black Antwerp A. ..	21–22	Perthshire A...	9.8	40.1	16.5	22.1
,, ,, ..	,,	,, B...	6.2	33.2	22.1	20.5
,, ,, ..	,,	,, C...	6.6	34.0	18.7	19.8
Baumforth Seedling B.'	21–22	Perthshire A...	9.9	31.8	14.2	18.6
,, ,,	,,	Kent A. ..	8.2	26.7	15.2	16.7
,, ,, ..	,,	Perthshire C.	9.7	30.2	10.0	16.6
,, ,, ..	22–23	Norfolk ..	—	28.4	20.3	24.3
Helston	21–22	Cornwall A.	11.8	39.2	27.7	26.2
,, ...	,,	,, ..	10.7	39.0	24.4	24.7
Baumforth Seedling A.	21–22	Essex	8.1	40.5	28.1	24.9
,, ,, ..	,,	Kent A. ..	11.6	32.6	16.6 (mosaic severe)	20.3
,, ...	22–23	Devon ..	—	8.9	16.5	12.7
Red Antwerp A. ..	21–22	Perthshire A...	4.3	22.0	13.5	13.3
,, ,, ..	,,	,, B...	3.6	13.0	19.3	12.0
Norwich Wonder ("Laxton").. ..	21–22	Perthshire C.—	4.8	24.2	22.2	17.0
Norwich Wonder ("Fillbasket") ..	22–23	Kent C. ..	—	9.2	30.6	19.9
,, ,, ..	,,	Kent A. ..	—	7.3	20.4	13.8
Storrie's Invincible "(Norwich Wonder" ?)	,,	Perthshire D...	—	11.5	20.4	15.9

Single rows of Pyne's Royal and Reader's Perfection, 360 feet long, were divided into twelve 30 foot lengths, each of which was picked separately throughout the season.

The average crop for each length, in ounces, was as follows :

Reader's Perfection	220.7 ± 9.67
Pyne's Royal	212.5 ± 5.81

The probable errors, expressed as per cents., are 4.38 per cent. and 2.73 per cent. respectively. This seems to us to indicate somewhat greater reliability than we had expected. But it must be repeated that very few of the figures in this report are based on material planted specially for cropping trials ; nearly all the material was planted specially for roguing, with a view to planting the main trials later.

Since mere weight of crop is by no means the only indication of a variety's commercial value, some notes on fruit qualities and time of ripening may perhaps be of value to readers.

The combination of qualities necessary to make a raspberry suitable for marketing in punnets is found, in our conditions, in only three or four varieties. Of these the best by far are Lloyd George and Pyne's Royal. Lloyd George is the better coloured and the better flavoured of these, but its fruit is only barely firm enough for the purpose ; and some people object to its shape as being too like that of a loganberry. The fruit of Pyne's Royal is firmer, and when well grown has a good smooth short-conical shape.

A promising variety fruited here for the first time in 1924 is North Ward, a Cornish sort which seems very difficult to obtain. In our conditions the fruit is larger than any variety except Lloyd George, and Pyne's Royal; it is nearly the same shape as Lloyd George, i.e., long conical, and of at least an equally good colour ; in firmness also it seems to meet requirements. A fourth variety which we ourselves have marketed in punnets is Norwich Wonder ; but of this variety the fruit is only large enough when well grown, and as the variety seems to have " off years " it cannot be relied on for the purpose. It has the disadvantage of a very short "strig," which makes it necessary to cut the fruits for punneting with sharp-pointed scissors. The flavour of the fruit is about the best of all raspberries. Storrie's Invincible appears to us to be identical with Norwich Wonder, but has produced stronger growth and larger fruit, two points in its favour. Hornet A. is often large enough for punneting, but its fruit is too soft, as is that of Profusion.

In the South of England many growers are in search of an early variety suitable for commercial use. The three varieties which prove here to be the earliest ripening are Mitchell's Seedling (Semper Fidelis B), Prior's Prolific, and Norwich Wonder. Of these the first and second have unfortunately suffered severely here from blue stripe wilt (" die back "), whilst the third as already stated is unreliable in cropping. They are, however, the only sorts that can be recommended for the purpose. Mitchell's is often known in Scotland as " Semper Fidelis ", but is quite distinct from the old English variety of that name. Bath's Perfection, which is early, succeeds nowadays in very few places, and cannot be recommended. Hornet A. also begins to ripen early, but the bulk of its crop is mid-season.

We sometimes also meet growers who want late varieties for extending their season. The latest of all is the variety which we now call " Hornet E. ", sometimes known as " Improved Hornet," or " Late Hornet ". This appears to be an excellent variety ; the fruit is of good size and produced in very large clusters ; even in Kent it seems usually to continue ripening well into August, (it has no tendency to flower on the new canes, and thus is not an autumn fruiter).

Next to this, one of the latest varieties is Devon ; a sort specially adapted to heavy soils. The bulk of the crop of Devon, however, would probably ripen on the average a good week before Hornet E.

We cannot of our own knowledge recommend varieties suitable for jam. We have often been told, however, that Baumforth A. and Semper Fidelis A. are about the best of all ; Pyne's Royal, Lloyd George, Mitchell's Seedling and Devon are also said to be good jammers. We have been told that amongst the worst are Baumforth B., Superlative and Norwich Wonder. Some jam makers appear to like both Red Cross and Bath's Perfection, whilst we know of cases where both varieties have turned out very poor jam ; perhaps the soil on which they are grown alters the jamming quality.

Finally, a few words may be added as to certain Continental varieties now on trial here. Winkler's Seedling appears to be a very heavy cropper ; the fruit is of very fine colour and good flavour, but in our conditions is distinctly small. If it will produce larger fruit in other soils it will be an extremely promising variety. Brown Hague has not cropped particularly well, and its fruit is of a rather dull purplish colour, but much larger than that of Winkler's.

A Dutch variety called " Roosjes " has cropped very well, and produced good sized fruit of fair colour. " Wilder," also from Holland, has cropped fairly well and appears to be distinctly late in ripening, probably later than Devon. A variety received from Holland as " Oude Zundertsche " proves to be identical with Hornet A.

PLATE VI.

F. Edenden.

FIG. 1.

TYPICAL WALNUT-SHAPED GALLS OF THE BLACKBERRY STEM GALL MIDGE (*Lasioptera rubi* Heeg.) (two-thirds natural size).

F. Edenden.

FIG. 2.

ALTERNATE GALL OF THE BLACKBERRY STEM GALL MIDGE (*Lasioptera rubi* Heeg.) (two-thirds natural size).

THE GALL MIDGES OF BLACKBERRIES AND RASPBERRIES.

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There are four chief midges (*Cecidomyidæ*) which do damage to Blackberry and Raspberry plants. The adult fly in each case is small and liable to be overlooked. The Blackberry Stem Gall Midge (*Lasioptera rubi* Heeg) produces a hard walnut shaped gall on the stem, the Blackberry Leaf Midge (*Perrisia plicatrix* H. Loew) damages the leaves by causing them to curl up and the mid-vein to swell and become distorted, the Blackberry Blossom Midge (*Contarinia rubicola* Rbs.) infests the buds causing damage which is similar to that caused by Thrips, and the Raspberry Cane Midge (*Thomasia* sp.) causes the outer rind of raspberry canes to peel off. All the three former midges are commonly found on wild blackberries and so it is very difficult to get rid of them.

THE BLACKBERRY STEM GALL MIDGE
(*Lasioptera rubi* Heeg).

Insect.—This is a small midge with large black contiguous eyes, the thorax is brown, darker dorsally, with its anterior margin with a silver band ; the abdomen has five dark bands formed by black scales and behind each band is a band of silver white scales. The general appearance of the insect is black and silver, with a white spot at the base and another half-way along the anterior margin of each wing. The lower half of the anterior margin of the wings appears black owing to the scales on the costal and sub-costal vein.

The larvæ are orange-red, about $\frac{1}{10}$ in. length, and have a bifid " breast-bone " or " anchor process." Houard (1909) says the larvæ are white, but this is probably an error.

Gall Damage.—The galls are made on wild Blackberry (*Rubus* sp.) most commonly, but also on the cultivated Raspberry (*Rubus idæus*). Theobald writes (R. S.E. Agric. Coll., 1904) " damage in 1898 very apparent, few leaves and no fruit " and Collinge (Man. Inj. Ins., 1912) " not only do young shoots die, but the canes become liable to be attacked by a fungus . . . large numbers in past few years." The galls are usually formed as elongate walnut shaped swellings (Fig. 1) on all parts of the stem, and are sometimes as much as one inch in length. There is however, another form of gall which is a flattened eruption of the stem and causes the stem to droop (Fig. 2). Each gall may contain up to seventeen red larvæ but usually about twelve. Besides the red

midge larvæ, one often also finds a white larva with no breastbone, which is the larva of a hymenopteron. The exact part played by this larva is not quite certain but it is at present thought to live on the midge larvæ as an external parasite at any rate in its later stages.

Life History.—The adult midges hatch during May and June and the female lays from 8—15 eggs at the base of the buds. In about ten days the young larvæ hatch, and eat their way through the epidermis. The swelling galls first makes their appearance about three weeks later, but are not easily seen until the autumn when the foliage is less dense. The larvæ remain in the larval state in the gall until the following April when they change into pupæ. After about a fortnight the perfect insect or midge emerges.

Remedy.—The best way to get rid of this midge is to cut out the galls in the autumn and winter and burn them. But this will not prove effective unless the neighbouring wild blackberry bushes are treated in the same way.

THE BLACKBERRY LEAF MIDGE

(*Perrisia plicatrix* H. Loew).

Insect.—This midge, smaller than the last, is a pale flesh colour with the dorsal part of the thorax brown, in both sexes. The male is smaller than the female which has a long retractile ovipositor. The male antennæ are 2 + 12-jointed while the female ones are 2 + 13-jointed.

Gall Damage. The damage caused by the larvæ is a folding of the leaves along the mid-vein, which gets swollen and distorted. The larvæ make this gall on Dewberry (*Rubus cæsius*) and other species of Blackberry (*Rubus* sp.). It is also found on the American Blackberry (Kent, 1925) which is grown for cultivation.

Life History.—The adult midges lay their eggs on the leaves during late May and June. The larvæ which are white live gregariously in the curled leaves until they are fully grown which usually takes about three weeks. The larvæ then leave the leaves and pupate in the soil. After about fourteen days a second generation of midges hatch out and these are on the wing in July and August. The full grown larvæ resulting from these midges pupate in the soil over winter emerging the following May and June. Thus there are at least two generations during the year.

Remedy.—Digging in the soil under the blackberry bushes deeply during the winter will render the emergence of the midges in the following spring more difficult. Gathering and burning the infested leaves when they appear will also be effective. But as this midge also infests wild Blackberries, care should be taken to see that the neighbouring hedges are also free from infestation.

PLATE VII.

C. A. W. Duffield.

FIG. 3.

FEMALE RASPBERRY CANE MIDGE (*Thomasia* sp.) (× 40).

C. A. W. Duffield.

FIG. 4.

DAMAGE DONE BY RASPBERRY CANE MIDGE (*Thomasia* sp.) (natural size).

THE BLACKBERRY FLOWER MIDGE

(*Contarinia rubicola* Rbs.).

Insect.—The adult midge is in the case of the female 1.6 mm. long. The eyes are black, antennæ have 2 + 12-joints and the thorax is glossy dark grey. The abdomen is dirty yellow with broad grey brown bands dorsally.

Gall Damage. The larvæ live in the buds of Dewberry (*R. cæsius*) and other wild Blackberries (*Rubus* sp.) and also of the cultivated American Blackberry (Kent, 1924-25). The buds are swollen and remain unopened, the petals are more than usually crinkled, while the stamens are blackened and dried up. This damage prevents fruiting in extreme cases or badly shaped berries in cases where less larvæ are present. It resembles the damage caused by Thrips.

Life History.—The midges hatch in June and July and lay their eggs inside the buds at the base of the stamens. As many as twenty-seven larvæ may be found in a single bud. They are white in colour and when fully fed "jump" out of the bud to the soil where they pupate and winter. They "jump" by folding themselves into the shape of a bow and then release themselves with a spring-like result. It is recorded on the continent from France (Pierre, 1906) and Germany (Rübsaamen, 1910). Theobald found it on American Blackberry in Kent in 1924 while the writer found it again in different localities in Kent on American Blackberry and wild Blackberries in 1925.

Remedy. The only way yet known for getting rid of this midge is to pick the deformed buds in July and August and burn them.

RASPBERRY CANE MIDGE

(*Thomasia* sp.).

Insect. The midge in this case is about the same size as the Blackberry Leaf Midge. It is ochreous in general appearance, with clear wings. The joints of the male antennæ are bilobed except the two basal ones, while all those of the female are cylindrical. The dorsal part of the thorax is dark brown and the eyes are black (Fig. 3).

Gall Damage.—The larvæ have only been found on "Bath's Perfection" variety of Raspberry. They are reddish in colour with a bifid "breastbone." They live under the outer rind of the canes, and appear to attack the well grown canes just as much as the younger ones. The result of the attack is that the rind peels off and the top shoots die off (Fig. 4).

Life History.—The larvæ first become evident in July and the attack begins to wane about half way through August. Most of the larvæ then go to the soil to pupate over winter. The adult midge is on the wing during the early part of

July. Very little is known about the exact life cycle of this midge, but it appears to be restricted to the one variety of raspberry, and other varieties grown side by side with Bath's Perfection have always been found to be immune from attack. Theobald recorded a bad attack of this midge in 1920 from Kent and Surrey.

Remedy.—No remedy is yet known, but it is thought that digging in calcium cyanide powder into the soil round the canes during the winter will kill any pupæ that are there. A parasite has been reared this year which killed 100 per cent. of the larvæ collected from two districts, but a mild attack of the midge was later reported from one of these districts so that too much hope must not be attached to this parasite.

The writer is indebted to C. A. W. Duffield, Esq., for permission to reproduce Figures 3 and 4.

ILLUSTRATIONS.

Fig. 1.—Typical walnut-shaped galls of the Blackberry Stem Gall Midge (*L. rubi* Heeg) (two-thirds natural size).

Fig. 2.—Alternate gall of the Blackberry Stem Gall Midge (*L. rubi* Heeg) (two-thirds natural size).

Fig. 3.—Female Raspberry Cane Midge (*Thomasia* sp.) (x 40).

Fig. 4.—Damage done by Raspberry Cane Midge (*Thomasia* sp.) (natural size).

NOTES ON SILVER-LEAF.

By F. R. PETHERBRIDGE, M.A.,
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I.—SILVER LEAF IN PLUMS.

In the course of inspections of fruit plantations, I visited in 1919 a plantation of Victoria Plums of enormous cropping power belonging to Mr. W. T. Afford, of Bluntisham, near St. Ives in Hunts. in which the silver leaf fungus was killing considerably fewer trees than is usual in the Eastern counties. As this district has suffered serious losses from this disease, the above plantation suggested itself as a suitable place for the field study of the incidence of this disease. In 1920, I decided to keep a careful record of these trees and to study Mr. Afford's methods in order to find out if possible, some procedure which might be of assistance in reducing the damage caused by silver leaf.

The plantation contains in addition to other varieties ten rows of Victorias on Myrobolan stock of about forty trees in each row, planted eighteen feet apart. The trees were budded low down on the stock and planted in 1898. For several years after planting the trees bore very little fruit (the first full crop was in 1908), but made exceptionally strong growth with the result that at the present day the branches are very large and strong (see Fig. II.B) and capable of bearing an enormous crop of fruit without the harmful effect of the breaking of the branches so common in trees in East Anglia. The soil is a well drained clay with a slight slope and is particularly suited to the growth of plums. In certain seasons these trees have borne the largest crops of plums that I have ever seen in a commercial plantation.

Silver leaf is very prevalent in the Bluntisham District, but up to 1919, Mr. Afford had lost only thirty-nine trees (about 10 per cent.). The first two trees were removed in 1908, so the average loss since that date is about one per cent. per annum. The Table on the following page gives the record of the trees since that date.

In this Table, trees which were apparently free from silvering but which became silvered *again* the following year are recorded as silvered trees.

The figures show that in this plantation the silver leaf fungus has not (since 1920) caused the serious damage which is usual in Victoria plums on Myrobolan stock in this district.

It is very difficult to say from these figures how many of the trees have become healthy through natural recovery and how much is due to specific treatment and in this connection it should be pointed out that uncut silvered trees which did not recover the following season were then cut and consequently

	1920.	1921.	1922.	1923.	1924.
Trees removed through Silver Leaf	11	0	0	2	0
Trees recovered from Silver Leaf without cutting out branches	—	3	10	10	11
Trees showing no Silvering subsequent to the removal of silvered branches	6	10	27	30	30
Trees with silvered foliage, no branches cut out	16	10	2	3	2
Trees with silvered foliage after removal of silvered branches	26	37	25	20	23
Total Trees with silvered foliage	42	47	27	23	25
Fresh Cases of Silver Leaf ..	—	12	5	1	3
			one silvered tree removed to make way for a shed.		

the trees which did not naturally recover are then included under the "cut" group.

Natural recovery. One fact stands out and that is that the greatest natural recovery took place during the dry period of 1921-22. In 1921, three silvered trees recovered and in 1922 seven more recovered whereas in 1923 no trees recovered, and in 1924 only one tree recovered.

The freedom from silvering of the "cut" trees was also greatest during the dry period. In 1921, four trees remained free and in 1922, seventeen more remained free from silver leaf as against three more in 1923 and three more in 1924. (The number of apparent recoveries was also the greatest in 1922.)

It will be noticed that only two trees (or less than one per cent.) have been removed through silver leaf during the last four years and presumably the cutting out of the silvered branches has been the means of preventing further loss.

MR. AFFORD'S METHOD.

The soil round the trees is hand-forked, but between the rows the soil is shallow ploughed and worked in the usual way to keep it clean. The weeds only grow sparingly under the normal trees probably owing to the dense shade.

Manuring.—A good dressing of farmyard manure is put on in the autumn after a heavy crop (heavy crops were pulled in 1919 and 1922), and followed in the early spring with a dressing of dissolved bones at the rate of 7 cwts. per

PLATE VIII.

Fig. 1.

Victoria Plum on Myrobolan Stock, showing the re-building of the tree after the "hat-peg" method of cutting out.

acre. No other manure is used until the next heavy crop is well set when a late spring dressing of artificials containing ammonia and phosphates (at the rate of 2 cwts. per acre) is given.

Cutting out of Silvered Branches.

The date of removal of the silvered branches varies with the season, but is done before the *middle of May*. Mr. Afford's reason for cutting out early is "not only does the wound callus over quickly, but the most important point is to get midsummer shoots and begin building up the tree at once." The trees are further examined at frequent intervals and when silver leaf is found it is usually removed during the next forty-eight hours and burnt.

This immediate removal of silver leaf branches (even if loaded with fruit) is probably one of the factors which helps to check the damage caused by the fungus.

The method of cutting out of silvered branches is somewhat unusual. Whenever possible the silvered branch is cut back to a healthy lateral. Where no healthy laterals are present on the branch it is not cut back to the trunk but is cut back so as to leave one to two feet of stump—provided the end of the stump shows no dark stain in the wood due to the silver leaf fungus. This hat-peg method of pruning is shown in Fig. I.

The object of leaving these hat-pegs is in the hope that these stumps will send out adventitious shoots which will quickly build up the part of the tree which has been removed. Fig. I. shows one side of a tree being built up in this way after the silvered branches have been removed and burnt.

Even when the hat-peg sends out no adventitious shoot it is still left on the tree.

The ends of the hat-pegs are not covered with any preparation to prevent the entrance of the silver leaf fungus.

When practically the whole of the tree is silvered and it is impossible to cut back to healthy wood, the tree is marked to be taken up during the winter but one or two cases of recovery have taken place where these trees were left in.

At the present stage of our knowledge of the silver leaf fungus, it would seem that Mr. Afford's success partly depends on his cutting out of the silvered branches at a time when there are very few spores of the fungus being formed. Brooks and Storey* have shown that freshly exposed wood is most liable to infection by this fungus and that the risk of infection is small after the branch has been sawn off for a month.

When Mr. Afford saws off his branches there are probably few spores to infect the wound and when the spores are abundant in the autumn they are apparently unable to infect the cut surfaces.

* *Loc. cit.* Vol. III., No. 3. 1923.

The "hat-peg" method has certainly proved itself to be economic in this case by the more rapid building up of the tree for future crops.

It should also be noted that these trees were so treated in the early years of growth that they now have big branches capable of bearing enormous crops without breaking whereas in most orchards in East Anglia a big crop breaks a large number of branches unless they are supported.

Another point which may be of some importance in connection with silver leaf is the picking of the fruit. Mr. Afford is very careful in this matter to see that the trees are injured as little as possible during this process.

The above trees are growing in good plum land ; the trees were well pruned in the early stages, and the cultivations and manuring are adequate.

The spraying of these trees has been rather below the average, some seasons they have been sprayed with Lead Arsenate and in others with Soft Soap and Nicotine.

Replanting. A large number of growers think it unwise to put a young plum tree in the ground from which a silvered plum tree has been removed. Up to 1919, Mr. Afford planted apple trees when the plum stumps were removed, Odd apple trees in a piece of plums are a nuisance both from a spraying and picking point of view. In 1920 twenty-two young Czar plums were planted in the site of the trees which were removed the two previous years and since that date silvered trees removed have been replaced by plums. None of these trees has died and only one has shown silvering.

From the above and similar observations it is obviously the most economic plan, in a plum plantation which is doing well, to replace trees removed owing to silver leaf with other plum trees. There seems to be very little danger of the young plum becoming infected from the previous tree provided the latter is removed and burnt.

The following statement of Brooks and Bailey* supports the view that freshly planted plums are not likely to be infected from the old roots of previously removed silvered trees. "The possibility of root infection was not excluded where diseased roots came in contact with healthy ones, but we have not yet observed any trees, which indubitably became infected in this way."

The Influence of Root Stock.

Mr. Afford's plantation also provides a striking example of the influence of the root stock on susceptibility to silver leaf and the killing power of the fungus.

On three sides of the plantation are 129 Victoria plum trees grafted about four feet from the ground on Common plum stock found growing wild in the

* *Journal Agricultural Science*, Vol. IX., p. 208, September, 1919.

PLATE IX.

A. Fig. II. B.

A. Victoria Plum on "Common Plum" Stock. B. Victoria Plum on "Myrobolan" Stock.

Both trees were planted in 1898.

neighbourhood. Owing to the dwarfing nature of this stock (see Fig. II. A) these trees are planted twelve feet apart in the rows, but the rows are eighteen feet apart as compared with eighteen feet square for those on Myrobalan stock. These trees were planted in 1898, i.e., at the same time as the main piece of plums.

Mr. Afford states that none of these trees had died from silver leaf although occasionally the foliage of a few were silvered.

In 1919 one tree died but not from silver leaf.

In 1920 only three trees showed silvering of the foliage. On one tree one lower branch had been badly silvered for several years and was then partly dead. This branch continued to bear silvered foliage until 1923 when it was cut out and in 1924 no silvering was seen.

Another tree was badly silvered in 1917, 1918 and 1919 but in 1920 the silvering was very slight and only the first leaves in spring were silvered. Later in the season the foliage was normal. No cutting was done and since then this tree has shown no sign of silvering. The other silvered tree has a bad wound at the graft and has been silvered every year since.

In 1921 another tree had its main branch badly silvered. This was cut out in 1922 but one branch showed slight silvering in 1924.

In 1922 no fresh cases of silvering were noticed.

In 1924 two fresh cases of bad silvering were noticed.

Since 1919 out of 129 trees none of these trees has died and only six have shown silvering of the foliage.

When this record is compared with those on Myrobolan stock it is obvious that the losses occasioned are very much less than those on the latter stock, and the working of Victorias on common plum stock should prove of economic value in reducing losses from silver leaf.

There is one difference in the working of the above trees which may or may not have some bearing on the problem. The trees on the common plum stock were grafted at standard height (about four feet from the ground) where those on Myrobolan were budded in the usual way, low down on the stock.

It is of interest to compare the cropping power of Victorias on these stocks, concerning which Mr. Afford has sent me the following particulars :—" The Victorias on common plum stock are twelve feet apart in the row and eighteen feet apart from the next row, whereas those on Myrobolan are eighteen feet square. There are roughly forty trees per row on Myrobolans and sixty trees per row on common plum stock.

" In a heavy cropping year I have compared two rows and I find that the sixty trees on common plum carry about the same crop as forty of the others, viz., five tons.

" In the poorer years sometimes one is the better and sometimes the other, but on the average one is as good as the other.

"The variation in cropping is due, I think, to the fact that those on Myrobolan blossom about three or four days earlier than the others, therefore they sometimes get better conditions at the critical time of the setting of the fruit, and sometimes worse.

"I think Victorias on common plum stock should be planted fifteen feet square as compared with Victorias on Myrobolan at eighteen feet square."

Work on the influence of stock on this disease is being carried out by Brooks and Hatton at East Malling.

The writer wishes to express his thanks to Messrs. W. T. Afford, W. A. R. Dillon Weston and D. Boyes for their assistance in making the above observations.

II.—SILVER LEAF IN APPLES.

In pre-war days Silver leaf in apples was not at all common, but since that time cases of serious damage have been brought to my notice.

The variety which has suffered most in the Eastern Counties is Early Victoria (Emneth Early), but Lord Grosvenor and Newton Wonder have also suffered badly. My attention was first called to the damage which silver leaf could cause to apples in May, 1920 by Mr. H. S. Littlechild, of Leverington, near Wisbech.

He complained that he had taken up nine Early Victorias as a result of silver leaf, that thirty more of this variety were silvered, and in addition two Grosvenors and one Newton Wonder showed silvering. The cause of this silvering was most probably the cutting out of large branches in order to facilitate the cultivation of the land. Old and young fructifications of Stereum purpureum were present on the snags where the silvered branches were sawn off.

In 1921 out of 350 Early Victoria trees about ninety trees were silvered, and out of 100 Grenadiers twelve showed silvering.

Mr. Littlechild has supplied me with the following particulars for 1924.

Variety.	Number of Trees.	Number of Trees ever showing silvering.	Number Removed.	Number Recovered.
Early Victoria (Emneth Early)	350	112	17	about 50%
Grenadiers	100	25	2	13
Lane's Prince Albert	200	5	1	4

A case of much more serious damage was brought to my notice in 1921 near Long Sutton in Lincolnshire. Two orchards separated only by a road and

containing no plum trees were badly neglected during the war. Here again large branches were cut out to facilitate cultivation and fructifications were present on the snag. In the small orchard the rows were alternately Bramleys and Early Victoria. Of the 660 Early Victorias over 400 showed silvered foliage.

In the large orchard every other row was Early Victoria and out of 1500 trees only about 500 were free from silver leaf.

The other rows contained Bramleys and Lord Grosvenor. Out of about 300 of the latter, 144 showed silvering of the foliage. Very few of the Bramleys showed silvering.

A few of the Early Victoria and Grosvenor trees were dead and carried fructifications of Stereum purpureum and some of the trees were dying.

A visit to this orchard the following winter showed that over 50 per cent. of the Early Victoria trees bore fructifications of Stereum purpureum on the cut surfaces where branches had been sawn off. A visit to these orchards in 1922 showed that about 40 per cent. of the silvered Early Victorias had recovered and only about 5 per cent. of the trees had died. Fructifications of Stereum purpureum were abundant on the trunks which had not been removed.

On visiting these orchards in February, 1925, I found that the bulk of the trees had been removed and the remainder were being pulled up. In the remaining rows of Early Victorias not more than about 5 per cent. of the trees had died, but many of the trees that were being pulled up were badly stained in the wood of the stem.

From the above observations it will be seen that even in orchards containing no plum trees and with no obvious immediate source of infection from the silver leaf fungus, varieties of apple such as Early Victoria and Grosvenor trees are liable to heavy infection if large branches are removed.

Where possible varieties like Early Victoria should be so grown in the early stages so as to make the removal of large branches unnecessary when the trees are older. Where it is necessary to remove large branches, this should be done during the season when infection is least likely, probably during dry spells during late spring and summer, and the wounds covered with some material to prevent infection by the spores.

It may be merely coincidence, but I think it is worth noting that silver leaf in apples has been much more prevalent in trees on the light silt soils (especially between Leverington and Long Sutton) that on the heavier soils in the Wisbech district.

BOOK REVIEW.

SYSTEMATIC POMOLOGY. U. P. Hedrick. New York. The Macmillan Co. 1925. 488 pages, 303 text figures, 24 plates.

Systematic Pomology has not received much attention from British writers in late years, or indeed at any time. In America the numerous horticultural courses given at Colleges have caused a demand for such text books and the *Systematic Pomologies* of Budd and Hansen and that of F. A. Waugh issued in 1903, have for long held the field alone. The *Horticultural Manual* of Budd and Hansen was a serious contribution of 487 pages, while Waugh's book was shorter by some 200 pages. Such works, however, are bound to get out of date in twenty years and we therefore welcomed the news that Prof. Hedrick was to produce a successor.

It is with some disappointment, therefore, that we find in this work evidences of hasty production, and many sweeping statements that cannot be justified. The arrangement adopted is good ; a definition of Systematic Pomology is followed by a consideration of leaves, stems, buds and other parts of the tree and their value in classifying and describing fruits. Methods of working are given and each class of fruit is then considered in detail.

The statements which cannot be justified may be illustrated by a paragraph on p. 14 where it is said that " European Gooseberries are stocky with upright straight branches, while American Gooseberries have slender stems which curve, droop, spread or sprawl." A reference to Hogg's *Fruit Manual* or many English Fruit Catalogues would have shown that the spreading habit is quite common in European varieties and, like all other fruits of which we have large numbers, fastigiate, weeping and all intermediate forms of growth are present.

Again on p. 34 it is stated that the leaves of sweet cherries droop on account of their slender petioles. This however cannot be taken as a rule as there are several which have short stiff petioles which hold the leaf upwards, as for example the well-known Napoleon.

We are told that Pomologists have " paid almost no attention to the flowers of the several fruits," a statement true indeed of American authors but not of European. We recall the careful floral drawings of Poiteau and the minute descriptions of Mas as evidence to the contrary.

In the discussion of the stems of pome fruits no reference is given to the very remarkable difference in apples, both in shape of fruit, length of stem and depth of cavity when the central flower sets compared with one of the lateral blooms. The value of the dried style in the fruit is not alluded to, though the heading of section 100 leads one to suppose its inclusion was intended.

In the interesting discussion of the species from which the various fruits have been derived the author's previous work leads us to expect some detailed treatment, but here revision will be necessary in a future edition.

In discussing the Currants the old name *Ribes Sativum* of Syme is retained, whereas most modern authors have accepted Janczewski's authority for *R. vulgare*. The authority for the sub-variety *macrocarpa* is Janczewski, not Bailey.

In the Pear species the author places almost all under *P. communis* and the remainder from *P. serotina*, the Chinese Sand Pear, and *P. nivalis*. However doubtful may be the part played by other species such as *P. siniaca* and *eleagrifolia* and other Eastern European inhabitants some indication should have been given of the possibility.

In the Rubi species from which the Raspberry and Black Berry have derived corrections are needed under *R. strigosus*, *R. Idaeus* and also in *R. invisus* and *laciniatus*.

Prunus domestica is minutely described on p. 136, but no indication is given that it is merely a botanical abstraction, an imaginary parent for our European Plums which has not yet been found wild. Whether the leaves will be " large " and the pedicel " stout and pubescent " when it is, if ever, discovered, remains to be seen.

To come to general matters the descriptions blanks suggested smack rather of the study than of the field, as for instance a disregard for the pose of the leaf and habit of the tree.

The keys provided by the author follow the usual botanical lines and work fairly well with small numbers such as he describes but would we fancy break down under a more severe strain.

The text figures are not any too well drawn, some being quite misleading, as the Yellow Egg Plum on p. 194 and the Cherries Schmidt, Coe and Windsor, the last being so oval that we wonder if it can be the original variety which the raisers figured as markedly oblate.

More than half of the book is devoted to descriptions of fruits and we think, in view of the author's recent *Encyclopædia of Fruits* in which the same descriptions appeared, that this part might have well been omitted in view of the cost and weight of the book.

Students of Pomology will find much of value in this publication but they must, as in all other books of its kind, bring a critical mind to its reading, and our comments made above will we trust be accepted by the author as a testimony to a careful reading and a desire to make a good thing still better.

E.A.B.

STUDIES IN THE ROOT AND SHOOT GROWTH OF THE STRAWBERRY. I.

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I.—INTRODUCTION.

Of late Strawberry troubles have come into prominence and very little is known of the causes lying behind the production of abnormal Strawberry plants. When the investigation about to be described was commenced, a certain number of abnormal forms of the plant were ascribed to an eelworm, *Aphelenchus fragariæ* (1). Further work was needed to confirm these conclusions and in addition other forms of diseased or abnormal plants were observed in the field which showed none of the symptoms usually associated with the presence of *Aphelenchus fragariæ*. In July, 1924, certain plants at Long Ashton were noticed to wilt rapidly and later the foliage became brown and died. On examining some of these plants certain brown patches could be seen on the roots and there seemed the possibility that some fungus was the cause of the condition. The question naturally followed as to how much root a Strawberry plant of a given age should have, whether any of the root died annually, and if so how much, and at what season were new ones produced. In addition some information was required about the point of origin of the new roots. On examining several three year old plants in the field it was noticeable that the vigour of the plant was often associated with the degree of contact between the crowns and the soil. Plants whose crowns were not in contact with the soil were generally much inferior in vigour to those which had soil well up to the level of the new crowns.

Besides the value of a knowledge of the normal annual cycle of root and shoot growth of the Strawberry to the investigator of pathological conditions, it should be of some service to the grower himself—some new light might be shed on which is the most advantageous season for the application of manures or for assisting growth by perhaps special cultural operations. For these reasons this investigation of the growth of the root and shoot of the normal strawberry plant, and of some of the factors likely to influence the normal cycle, was commenced by the writers in the Autumn of 1924. In presenting an account of the work done in the season 1924-25, they do not wish the reader to infer that they would suppose that exactly the same results would be obtained in another locality or, in another season, in which the prevailing meteorological conditions were very dissimilar to those of 1924-25, but it was thought that the results so

far obtained were of sufficient value to merit immediate publication.* The work will be continued for several seasons, in which more than one series of plants will be examined throughout three growing seasons—the usual length of life of a strawberry plantation. This will give the opportunity of confirming the results of one season by those of another and at the same time ascertaining something of the seasonal effect. In addition the results will be checked by observations on plants growing under conditions of soil and climate different from those prevailing at Long Ashton.

II.—HISTORICAL.

A survey of the literature on the strawberry has been made and so far no reference to any work of a nature similar to that described in the following article has been found. Much of the published work in Europe and America deals with the various varieties and their cultivation. To the British strawberry grower much of the American work is of little value as American conditions are so different from ours that different varieties and special methods of cultivation are employed. For example, Royal Sovereign, one of our standard varieties, is unknown commercially in America. The whole subject of strawberry growing in North America is exhaustively treated by Fletcher (2 and 3). W. T. Macoun (5) in Canada describes some experiments on special cultivation and treatment of runners before planting. Similar experiments have been carried out in the present investigation. It is not proposed to give a complete bibliography of the strawberry here, but reference can be made to Fletcher (4), who quotes roughly eight hundred titles, many of which are bulletins or extracts from various horticultural journals, or to Payne (6) who gives a much shorter list containing the more important publications in English, French and German.

III.—GENERAL PLAN OF INVESTIGATIONS.

(I.) The desirability of a more precise knowledge of the behaviour of the strawberry plant, both above and below ground, has already been emphasised. The first portion of this investigation therefore consists in tracing the life history of the cultivated strawberry from the date of planting the runner through three consecutive seasons. An attempt will be made to correlate definite features in the normal annual sequence of the development of the plant with the meteorological factors of rainfall, sunlight and soil temperature.

* An account of observations on the effect of different methods of planting and on the root systems of abnormal plants will be found in a progress report in the Long Ashton Annual Report for 1925. When these observations have been amplified they will form the subject of another communication to this Journal.

(II.) The second portion of this investigation is designed with the object of discovering the effects of certain factors, other then meteorological, on the normal sequence of events. The particular factors to be investigated are :—

(*a*) The effect of the crop on the development of the plants in the first season from planting.

(*b*) The effect of the time of planting runners.

(*c*) The effects of different methods of planting, e.g.,

(i.) Deep planting.

(ii.) Shallow planting.

(iii.) Differing degrees of root trimming previous to planting.

(*d*) The influence of various methods of cultivation.

(III.) Finally, abnormal plants are to be examined with a view to finding whether the observed abnormalities can be attributed to defective root systems.

The plants used throughout the work in Sections I. and II. were obtained from a good strain of the variety Royal Sovereign. Details of procedure in the three sections of the work are presented in Section 4. below, the sub-sections of which correspond with those of the present section and are similarly indexed.

IV.—METHODS.

Approximately twelve hundred runners, variety Royal Sovereign, planted in the open ground at intervals of eighteen inches between the plants and thirty inches between rows, afforded the material for the first and second portions of the work. No attempt at special refinement was made, but the runners were sound, obtained from a reliable source, and normal methods of planting and subsequent cultivation were followed except in the special cases to be detailed. All the plants, except those reserved and heeled in for the experiments on different times of planting, were set out on 1st and 2nd of September, 1924.

(I.) In order to follow the normal course of events plants were lifted, in batches of ten, at intervals of three to six weeks throughout the season, the length of the interval being determined by close observation of the plants. In lifting care was taken to avoid damaging the roots and it was found necessary to remove the plant with a rough cylinder of soil eighteen inches to two feet in diameter and about twelve inches deep, adhering. Thus raised, the plants were allowed to soak in shallow tubs and the soil was carefully washed from the roots by means of a fine stream of water.

Careful observations on both roots and " tops " were made in the laboratory as quickly as possible and the subsequent treatment of the plants was as follows :

All leaves were cut off so that only the thickened leaf bases remained attached to the "crown" or rhizome. Next, all new main roots, which in the strawberry are adventitious and arise from the rhizome, were carefully detached and transferred to weighed beakers. The original runner roots, with any new lateral roots produced on them since planting, were similarly treated. The beakers containing these two groups of roots were immediately removed to a drying oven at 98° C. The portions of the plants remaining, namely, the short underground stems or rhizomes, after careful cleaning to remove soil particles and dead tissue, were dried with blotting paper and weighed. The fresh weight and the dry weight of the sample was obtained.

(II.) (*a*) Approximately two hundred of the plants planted in September, 1924, were deblossomed in May, 1925. Batches of ten such plants were lifted on the same dates as similar batches from the remainder of the September planted runners which had been allowed to bear a crop.

(*b*) Following the general planting in September, 1924, a further batch of some sixty runners was planted in the Spring of 1925 (April 7th). These spring-planted runners formed a parallel series with the normal September planted series and with the second group of plants described above in (*a*) The runners planted in April were deblossomed for the first season in the normal way, this operation being performed in May. Five plants were lifted on each occasion for comparison with plants from the two series to which reference is made.

The terms used throughout these descriptions are further explained in Text Figure I, which represents, diagrammatically, the average condition of a normal cropped plant in about the middle of July. The four types of roots present are numbered in the same order as they are described in the text.

V.—RESULTS FOR SEASON 1924-25.

A.—Qualitative Results.

(I.) THE NORMAL DEVELOPMENT OF THE STRAWBERRY FROM SEPTEMBER 2ND, 1924, TO SEPTEMBER 16TH, 1925.

September 2nd, Date of planting.

Both qualitative and quantitative observations were commenced on this date. The runners were well rooted and this root system, developed before transplanting, is referred to throughout the following observations as the runner root system.

October 13th. 6 weeks from planting. (Plate I. Fig. 1.)

At this date the runner root system could be distinguished readily from the roots developed since planting by the generally darker yellowish colour and

the presence of numerous new lateral roots. The original lateral roots and the tips on the main runner roots appeared to be dead or badly damaged. The production of new lateral roots had taken place near these points of damage, which had probably occurred in the regular procedure of runner taking, " heeling-in." and planting. The chief feature of interest in the root system at this stage was the development of numerous new " primary " roots from the portion of the crown immediately above the runner root system. These roots, all developed since planting, appeared in groups of from one to three to the right and left of the slightly sheathing leaf bases. On one plant fifteen of these roots were counted which ranged from 3.0 to 16.5 cms. in length, the average length being 10 cm. These roots were quite white and tender and were clearly of very recent origin. The strongest of these new " primaries" had produced secondary, or lateral, roots.

November 17th. 11 weeks from planting.

The runner roots were by this date quite brown from the points of attachment to the " crown " to within a few centimetres of the tips, but examination showed this browning to be superficial. Microscopic examination showed this discolouration and death of the tissues to be confined to the outer layers of cells or cortex. It is due to the formation of a layer of cork cells close to the central cylinder of the root. Thus, although the centre, or " core " of the root remains quite healthy the tissues outside this ring of cork cells are cut off from the necessary food supplies and eventually die. This dead brown tissue can readily be removed revealing the white central cylinder or " core " of the root. The writers regard roots of this type as perfectly normal. Usually the fine lateral roots in the brown region die, but in healthy plants numerous vigorous lateral roots are always present towards the tips where the formation of the secondary cork layer is incomplete.

Considerable development of new roots had taken place since the first lifting and numerous roots from 1 to 1.5 cms. in length were observed forcing a way through the lowest, decaying leaf bases. The average of the longest root per plant was 15 cm., the longest root measured being 21 cms. in length. Most of these new roots were at this date well furnished with lateral roots.

December 16th. 15 weeks from planting.

A considerable amount of root death, chiefly confined to the original runner root system, was observed. The dead roots were chiefly lateral roots from runner roots which had probably been damaged previous to planting. At this period after very heavy rains the experimental plot was in a badly waterlogged condition, a state of the soil well known to produce unhealthy root conditions. Further growth of new primaries was recorded, the average length of the longest new root

per plant was 16 cm., and copious production of lateral roots had occurred. In removing the new roots for weighing it was noted that a very few young roots showed a tendency to curl upwards and away from the crowns, others were quite dead. Examination revealed the presence of discoloured brownish regions on the affected roots chiefly on the side opposite to the crown. The presence of some parasitic root fungus was suspected and samples of affected roots were handed over to Mr. R. M. Nattrass, of this station, for examination. A fungus, thought to be a species of Fusarium, was isolated by him and a further sample of affected roots examined by Dr. Briton-Jones, of this Station, yielded the same fungus. The significance of these findings forms the subject of a separate investigation by the mycologists. The damage of the root system as a whole caused by this fungus appeared very slight and only a few very young roots on one or two plants seemed to be seriously affected at this date. Subsequent examinations failed to reveal any increase in the number of roots affected, on the contrary, it became increasingly difficult to find any roots showing signs of fungus attack and the writers are of the opinion that as a factor in the root development of the plants in the present investigation the presence of the fungus is practically negligible.

January 12th, 1925. 19 weeks from planting. (Plate I., Fig. 2.)

On the above date the browning of the cortex of the older runner roots had increased considerably and death of the lateral roots within the brown regions had advanced still further. The lower proportions of these main roots were still well provided with strong living lateral roots and in many of these browning of the cortex had also commenced.

The new roots produced during the nineteen weeks from planting had altered little in appearance since the previous lifting. No further growth was recorded and the production of lateral roots appeared to have ceased.

The condition of the foliage at this date was particularly observed. Most of the original runner leaves had by this time completely decayed and only two or three small and rather bluish-green leaves were present on each plant. These leaves had unfolded since the runners were planted and though much below normal in point of size, were of normal shape and texture.

February 16th. 24 weeks from planting.

Except for a pronounced yellowing of the new roots produced in the Autumn and further decay of the dead cortical tissues following the formation of cork, there appeared to be little alteration in the plants since the last examination.

March 16th. 28 weeks from planting.

This date marks approximately the recommencement of both root and shoot growth.

The old runner roots showed little alteration but the production of young lateral roots was just beginning on the new primary roots produced since planting. A few new primary roots had appeared intermingled with those produced in the previous autumn.

New leaves had just commenced to unfold and each of the ten plants examined possessed a well developed, but as yet unexpanded flower truss.

April 20th. 33 weeks from planting.

There seemed to be little change in the root system since the last examination except for the formation of numerous fine lateral roots, both on the younger portions of the runner roots and on the new primary roots.

The most marked change had occurred above ground each plant having unfolded two or three fairly large leaves. The blossom trusses had also commenced to expand.

May 11th. 36 weeks from planting.

The few new primary roots observed on April 20th had elongated and a varying number of new roots were developing on all plants. The total number of new main roots produced in the Spring was much below the number produced in the Autumn. New roots formed during the April-May period seemed to be rather of a supplementary nature arising between the roots developed in the Autumn, the largest numbers being found on plants which had made the least root growth in the period immediately following planting.

Shoot growth had progressed much more rapidly than root growth, and the average plant now possessed four or five well developed new leaves and an expanding flower truss, the central flower of which was usually beginning to open.

May 21st. 37.4 weeks from planting.

Two hundred of the September planted runners and all the runners planted in Spring were deblossomed on this date, the whole flower truss being removed at about one inch from the crown. The writers suggest that the notes immediately following should be read in conjunction with the notes given under the same dates on the deblossomed and spring-planted runners respectively, which are recorded in Sections II. (*a*) and II. (*b*) of the results.

May 28th. 38.4 weeks from planting. (Plate I., Fig. 3.)

New primary roots were still being produced; at this date an average number of four per plant was noted, and the average length of the longest new root developed on each plant was approximately 10 cms. The chief feature of the root system as a whole was the extensive formation of fine lateral roots both on

the younger portions of the original runner root system and on the majority of the new roots developed since planting.

The inflorescences, or flower trusses, were by this time fully expanded and the primary and secondary flowers had set fruit. The new leaves noted earlier in May had increased in size, but as yet no further new foliage had unfolded. The production of runners had commenced on stolons arising in the axils of the leaves which had opened in early Spring. The average length of the stolons was 12 cms., and usually only one had appeared on each plant.

June 26th. 42.6 weeks from planting.

Death of the cortical tissues of the runner roots had advanced markedly so that at this date these roots presented a uniformly blackened appearance, though they still supported a large proportion of vigorous white roots from the tips to within a distance of about 10 cm. from the crowns.

Secondary thickening with browning of the cortex had also commenced on the main roots produced since planting though some of the spring-produced new primaries were still quite white.

The beginning of a further development of new roots was observed on this date. At a distance of two to three centimetres above the latest developed Spring roots very young roots tips were observed forcing a way through the decaying leaf bases of the winter leaves. Few of these roots were more than a centimetre in length and the number per plant did not exceed seven. On three of the ten plants examined these roots had not appeared so far.

By this time the crop had been removed and the inflorescence stems were gradually dying back. On two plants lateral buds were observed near the base of the old flower stalk. The development of new leaves was just beginning.

July 20th. 46 weeks from planting. (Plate I., Fig. 4.)

From this date four distinct types of roots could readily be distinguished on a normal plant and these are described in the order of age and development. (See Fig. 1.)

(1) The runner roots showed considerable death of the small lateral roots, though they still supported a large proportion of the active root system.

(2) The autumn-formed new primaries showed a further advance in the secondary thickening noted at the last examination in June.

(3) The few primaries developed in Spring, intermingled with the Autumn-formed roots, had reached a stage of development comparable with that of the latter, about fifteen weeks from planting.

(4) The new primary roots observed in June developing from the base of the new crown growth had by this time increased considerably both in number

and in length. Similar new root formation was also taking place from the bases of the new crowns developed from axillary buds. (Plate III, Fig. 3)

The crowns had increased considerably in vigour and were producing new leaves. On the majority of the plants examined two daughter crowns were noted which had developed one on each side of the old flower stalk.

August 10th. 49 weeks from planting.

The general appearance of the roots at this date was much fresher and more vigorous owing to the formation of abundant lateral roots on (1) the runner roots, (2) autumn-formed roots, and (3) spring-formed roots. (4) A great increase in the number and length of the new roots arising from the base of the 1925 growth of the crowns was observed. The older of these roots were well furnished with lateral roots; the average length of the longest new root per plant was 14.3 cms., and the longest root observed measured 21 cms.

Top growth of leaves and runners was still very vigorous, the latter had been removed periodically in the field as it was decided to allow no runners to root in this particular investigation. Daughter crowns had developed vigorously and the average number of crowns per plant was 3.7.

The older leaves, i.e., those developed before cropping, were beginning to show purplish autumn tints and in texture these leaves were curiously brittle, a feature not observed on the later developed foliage.

September 16th. 54.3 weeks from planting. (Plate II., Fig. 1.)

(1) Runner roots seemed to be much darker and more twisted than the rest of the root system.

(2) Autumn-formed roots were in the main portions quite brown and showed a tendency to twist and contract.

(3) The spring-formed roots were also beginning to show browning of the cortex due to secondary thickening previously described.

(4) The new roots developed since the last examination showed a surprisingly large increase and now formed from one-quarter to one-third of the total system. (Plate II., Fig. 2). The average length of the longest new root per plant was approximately 17.0 cms., and most of these roots had produced abundant secondary roots and still finer "feeding" roots. The four types of roots recognisable on this date are illustrated in Plate III., Fig. 4.

New leaves and new daughter crowns were still being produced and the general vigour of the shoot growth seemed equal to that observed in August. Each plant on the average was now represented by four or five crowns, the increase being made up of lateral buds which had developed strongly since the cropping season.

II. (*a*) Deblossomed Plants (September planted).

June 26th, 1925.

The root systems were much more vigorous and better furnished with lateral roots than were those of the cropped plants. The browning of the old roots was much less noticeable and there were considerably more new primary roots.

The average number of crowns per plant was 2.5, and the daughter crowns had just commenced to form root systems ; no new root was longer than 0.5 cm. There were more leaves than on the cropped plants owing to the larger number of crowns. The average number of runners per plant was 5.4, and their average length was 50 cm. To sum up, both shoot and root were more vigorous than those of the cropped plants.

July 20th. (Plate I., Fig. 5.)

The old root system was of a browner colour than on June 26th, but was not so brown as that of the cropped plants. In addition there was considerably more lateral root development on these plants. The root system formed in the Spring and early Summer of 1925 was more vigorous than that of the cropped plants and was still white to yellowish in colour. The new roots were much more vigorous than those of the cropped plants, the new " primaries " being more numerous, longer (range up to 8 cm.), and stouter.

The crowns and leaves were considerably more vigorous than those of the cropped plants : in the field a sharp line could be seen by eye where the two treatments were adjacent. The cropped plants were much flatter than the deblossomed ones, the latter having more new foliage and runners and consequently appearing greener and more bushy. The bulk, both shoot and root, of the 10 plants examined at this date, was much greater than that of the 10 cropped plants. The average number of crowns per plant was 3.1.

August 10th.

A similar extensive root growth to that noted for the cropped plants had taken place. The number of new primary roots was greater, but on the whole the difference between these plants and the cropped plants was not nearly so marked as it was on July 20th. The average length per plant of the longest new primary root was 13.5 cm.

The general appearance of the crowns and leaves was more vigorous than that of the cropped plants. The average number of crowns was 3.6 per plant.

Bulk for bulk the crowns and root systems of the deblossomed plants were greater than those of the cropped plants.

September 16th. (Plate II., Figs. 3 and 4.)

The root system was still more vigorous than that of the cropped plants—the new primaries being more numerous and better furnished with laterals. The average length of the longest new primaries was 18.4 cm.

In the field the difference in vigour between cropped and deblossomed plants was still observable. It will be noticed, however, by comparing Plate II., Figs. 1 and 3, with Plate I., Figs. 4 and 5, that the difference is not nearly so great as it was on July 20th. The average number of crowns per plant was 4.7 cm.

(II.) (*b*) SPRING PLANTING.

May 11th, 1925. 5 weeks after planting.

Growth of new primary roots had taken place, as many as eight having been formed on the most vigorous plant. They varied in length up to 10 cm. On the old primary roots, i.e., the main runner roots, new lateral roots had been produced fairly abundantly. Observations on the shoot growth showed that two or three new leaves had been produced and that the first flowers were nearly ready to open.

May 28th, 1925. 7.3 weeks after planting.

A considerable further growth of feeding roots had taken place on the old runner root system. There were a few more new primary roots, and those which had been formed by the previous examination were now furnished with some laterals.

June 26th, 1925. 11.5 weeks after planting.

The old roots were well furnished with living lateral roots and there were one or two new primary roots since the previous examination. On the whole, the number of primaries formed since planting was very small—much smaller than the number formed on the autumn-planted runners in the corresponding period of three months from the date of planting. Observations on the shoot growth showed that three of the plants had one weak lateral crown each. New leaves were still being formed, but all the leaves, both new and old, were smaller than those of the autumn-planted plants. On the average there was one runner per plant, the length of none of the stolons being greater than 8 cm.

July 20th. 15 weeks after planting.

The original runner root system was by this time quite brown but was still furnished with living laterals. Further new primary roots had developed above the old root system and those formed since planting out before June 26th, had grown in length and were furnished with laterals. Further new roots could be seen just appearing through the leaf bases.

As a whole the root system of these plants was much smaller than that of the Autumn-planted runners, and the major portion consisted of the runner root system.

The shoot growth was not so vigorous as that of the September planted runners, the crowns being less thick and long and the leaves smaller. Considerable growth of stolons and runners had taken place since June.

August 10th, 1925. 18 weeks after planting.

Very considerable growth of new lateral and new primary roots had occurred since the last examination. The number and length of new primaries was noticeably greater than that of the September-planted plants, and in addition some of the new primaries were well furnished with laterals. The average length of the longest new primary roots was 15.3 cm.

Considerable shoot growth had taken place since July 20th and the leaves were more numerous and larger in size. The older leaves had not changed colour or become brittle as had those of the September—planted runners. The average number of crowns per plant was three.

September 16th, 1925. 23 weeks after planting. (Plate III., Figs 1 and 2.)

The runner root system was still well furnished with feeding roots. Some of the roots formed in the Spring and early Summer exhibited evidence of contractile powers and were well furnished with living laterals, more of which were still being produced. The new root system, i.e., that formed in the late Summer and early Autumn, was extremely vigorous and formed as much as from one-third to one half of the total root system. The primaries appeared to be better furnished with laterals than did those of either the cropped or deblossomed September planted plants. The average length of the longest new primary root on each plant was 22.2 cm.

Shoot growth was still very vigorous, new leaves were still being produced. but the bulk was not as great as that of either the cropped or deblossomed September planted plants. Since the beginning of August the increase in size of the plants as observed in the field was very noticeable, the plants being almost as big in some cases as those planted in September. The average number of crowns was five per plant.

Discussion of the Qualitative Results.

(I.) *The Normal Development.*

The effect of transplanting from the runner bed to the permanent quarters was to cause the death of the lateral roots and of the tips of the main runner roots. Very active root growth commenced soon after planting and continued until about the middle of December. The shoot growth was by no means proportional to the root growth made in this period.

A certain amount of root death was observed in December, but was ascribed to seasonal conditions and was not deemed to be of normal occurrence. There was a dormant period which lasted from the middle of December until the beginning of March, when growth of both root and shoot recommenced. In this second phase of growth which continued until the cropping season was ended, there was vigorous shoot growth, new leaves expanding, the flowers developing and the fruit maturing. The root growth was small, consisting mainly in the production of feeding roots on the scaffold roots already present, and only a few new primary roots were formed. What might be called the third phase of growth commenced after the cropping season and was still in progress in mid-September. This phase represents vigorous growth of both root and shoot. New crowns were formed resulting in great increase in the bulk of the plants. Root growth commenced at the end of June and was at first slow but became very vigorous by the beginning of August. This root growth consisted in the production of new primary roots and of new lateral roots all over the old root system. The new primary roots had their origin mainly at the bases of the new crowns, and above the point of origin of the older roots.

II. (*a*) *Deblossomed Plants.*

The effect of not allowing the plants to mature a crop of fruit was to increase the vigour of the plant. The deepening of colour of the older roots was delayed. The difference in vigour of root and shoot between the cropped and deblossomed plants, easily observable four weeks after the removal of the flowers, became most marked by July 20th but was not so noticeable by August 10th. The difference in vigour of the plants subjected to the two treatments was still observable in mid September, but the roots exhibited it to a greater extent than did the aerial portions of the plants.

(*b*) *Spring Planting.*

The root growth made up to midsummer by the runners planted in the Spring consisted mainly of the growth of new feeding roots, although a few new primary roots were formed. The commencement of a new phase of root growth was observable by July 20th, when new " primary " roots could be seen which had their origin distinctly above that of the older ones. A considerable growth of both root and shoot had taken place by August 10th. By mid-September as much as one half the total bulk of roots consisted of those formed since mid summer, a proportion greater than that observed for the Autumn-planted runners. At this date the difference in vigour between the plants set in Autumn and Spring respectively was much less than it had been hitherto, some of the Spring-set plants being as large as those planted in the Autumn.

B. Quantitative Results.

As described in the section on the experimental methods, data including the fresh weight of the crowns, dry weight of crowns and dry weight of roots were obtained on each series of ten plants lifted on the dates recorded above. These results for (1) the normal September planted or control series, (2) the September planted and deblossomed series and (3) the Spring-planted series are presented in Table I.

Changes in the percentage dry matter of the crowns are also recorded for each group of plants.

These results are further represented graphically so that a comparison may be made readily. (Figure 2.)

Discussion of Quantitative Results.

The results presented in Table I. and graphically represented in Text Figure 2 confirm those we have described as qualitative and yield further data on certain phases of the life cycle for which qualitative observations alone are inadequate.

Root Development.

The steady increase in the bulk of the root system from the time of planting in September up to the middle of December is clearly shown. During the so-called dormant period there was a marked decrease in the dry weight of the roots and this decrease is accompanied by death of cortical tissues following the development of an internal cork tissue. The slight increase in weight recorded in March is quite in accord with observations made on that date, when it was noted that a few new roots had made their appearance. From the middle of March to the middle of May there is a gradual decrease in the weight of the roots. Since the appearance of numerous new roots of the fine " feeding " type was recorded over this period this result at first sight seems surprising. This particular point is at present under investigation and the results obtained so far show that during the early stages of growth up to the opening of the flowers there is a very marked disappearance of food materials, especially starch, from certain tissues of the roots. During the period from May 28th to June 26th there is little change in the dry weight of the roots of those plants allowed to produce fruit. The deblossomed plants however showed a steady increase in root development during the same period. Increase in development of the roots of the cropped plants was recorded on July 20th approximately one month later than in the case of the deblossomed plants. The most rapid development occurred during July and early August, but the bulk of the roots was considerably behind that recorded for the deblossomed plants through the whole period from May till

TABLE I.

Summary of Quantitative Data on Samples each consisting of 10 *plants, for the three series.*

Date.	September Planted and Cropped Normal Series.					September Planted Deblossomed Series.					Spring Planted Deblossomed Series.				
	Weeks from planting.	Fresh wt. of crowns.	Percentage dry matter.	Dry wt. of crowns.	Total dry wt. of roots.	Weeks from planting.	Fresh wt. of crowns.	Percentage dry matter.	Dry wt. of crowns.	Total dry wt. of roots.	Weeks from planting.	Fresh wt. of crowns.	Percentage dry matter.	Dry wt. of crowns.	Total dry wt. of roots.
1924 Sept. 2	0	25.86	% 22.65	5.74	8.91			%					%		
Oct. 13	6	26.08±1.64	25.00	6.52	11.07										
Nov. 17	11	27.27±1.60	25.91	7.07	14.64										
Dec. 16	15	28.56±1.54	28.59	8.11	17.55										
1925 Jan. 12	19	27.39±1.84	30.41	8.33	17.70										
Feb. 16	24	21.82±1.70	25.03	5.51	13.23										
Mar. 16	28	24.85±1.77	24.94	6.21	15.31										
April 20	33	27.01	21.85	5.90	13.90							Apr. 7 Date of Planting.			
May 11	36	31.41	21.87	6.87	13.03						4.86	26.49	23.2	6.14	10.09
May 28	38.43	43.51	20.56	8.95	15.41			Deblossomed May 21st.			7.29	25.59	20.9	5.33	8.38
June 26	42.57	51.74	22.45	11.62	13.79	42.57	68.59	21.60	14.82	20.43	11.40	30.41	22.03	6.80	9.09
July 20	46.0	79.54	24.56	19.54	19.39	46.0	127.30	22.95	29.21	27.37	14.87	40.09	25.70	10.31	8.62
Aug. 10	49.0	118.90	25.40	30.20	29.08	49.0	134.46	24.44	33.86	32.16	17.87	56.12	21.45	12.04	19.67
Sept. 16	54.3	142.04	28.59	41.20	34.64	54.3	167.08	25.00	41.77	41.13	23.17	105.20	22.23	23.37	33.10

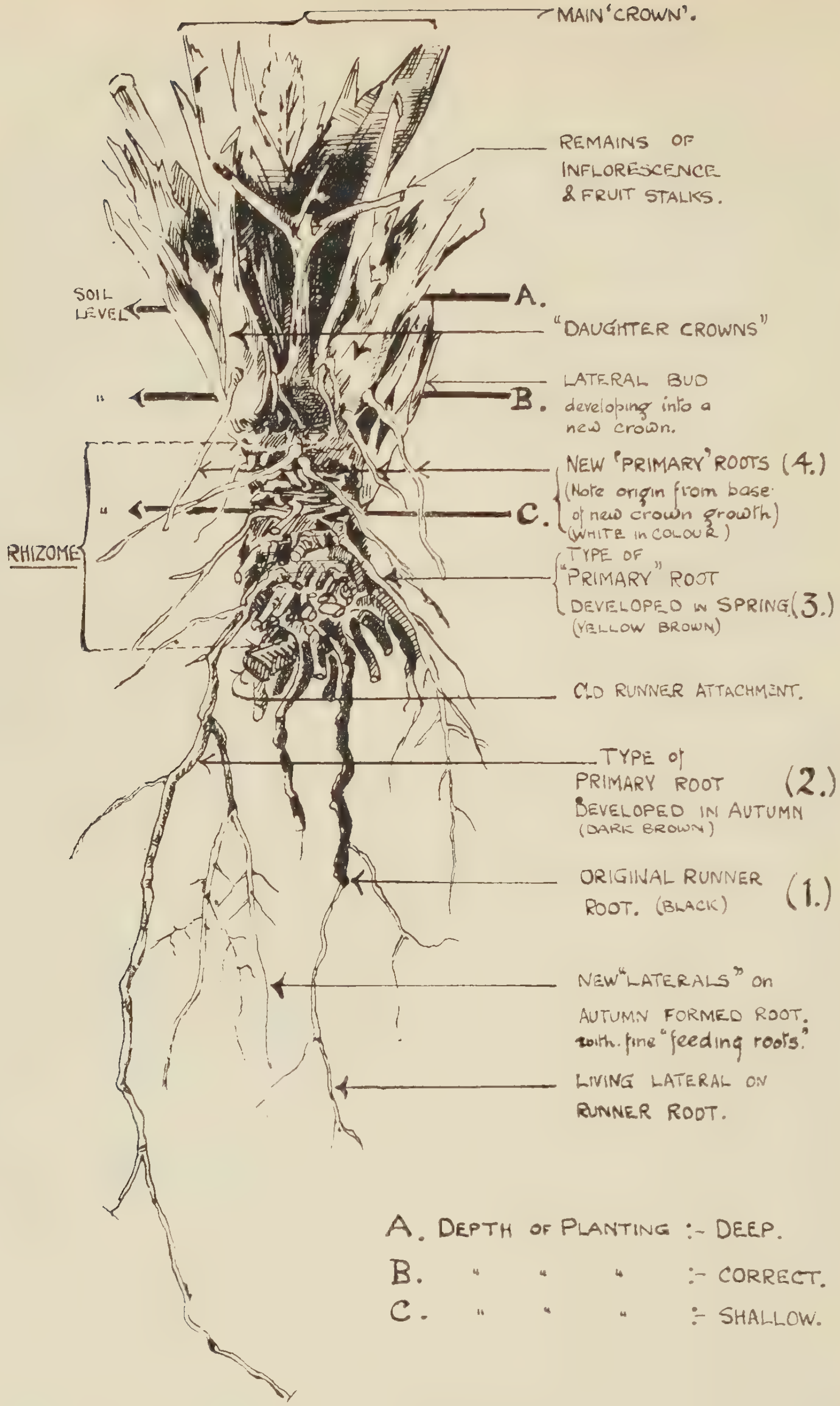
MAIN 'CROWN'.
REMAINS OF INFLORESCENCE & FRUIT STALKS.
SOIL LEVEL
A.
"DAUGHTER CROWNS"
LATERAL BUD developing into a new crown.
B.
NEW 'PRIMARY' ROOTS (4.)
(Note origin from base of new crown growth)
(WHITE IN COLOUR)
C.
RHIZOME
TYPE OF "PRIMARY" ROOT DEVELOPED IN SPRING (3.)
(YELLOW BROWN)
OLD RUNNER ATTACHMENT.
TYPE of PRIMARY ROOT DEVELOPED IN AUTUMN (2.)
(DARK BROWN)
ORIGINAL RUNNER ROOT. (BLACK) (1.)
NEW "LATERALS" on AUTUMN FORMED ROOT. with fine "feeding roots."
LIVING LATERAL ON RUNNER ROOT.
A. DEPTH OF PLANTING :- DEEP.
B. " " " :- CORRECT.
C. " " " :- SHALLOW.

FIG. 1.

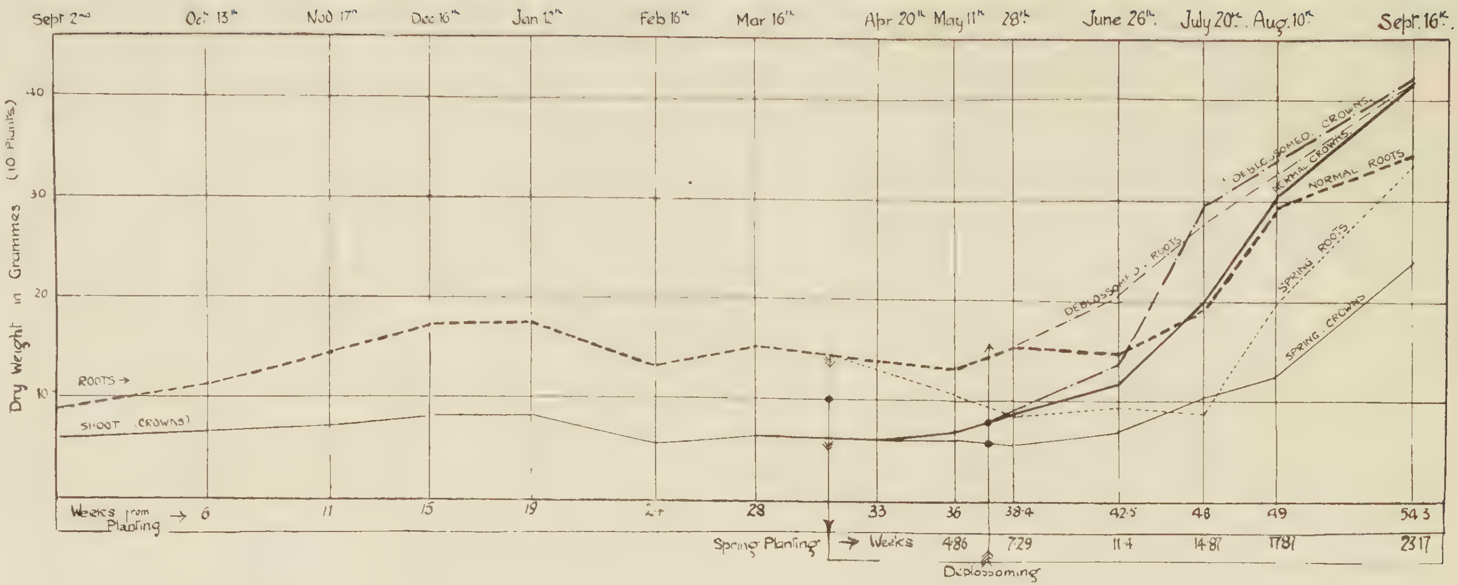

FIG. 2.

Showing the development of the roots and crowns of the plants in the normal series, deblossomed series and spring-planted series as indicated by changes in total dry matter.

September. Root development in the Spring-planted series commenced at a later date than in either of the other series, but was very rapid during the latter half of the Summer.

Shoot Development.

The portion of the shoot system weighed included the crowns or rhizomes, and the thickened leaf bases. The figures recorded do not include leaves, flower stalks or fruit. There was a gradual increase in weight from the time of planting till the middle of December, the increase in the percentage dry matter being very marked. During the dormant season and in the early stages of new growth activity there was a gradual decrease in the total weight of the crowns and also in percentage dry matter. From April 20th to May 28th, the period during which new leaves and flowers were expanding, there was an increase in total weight of the crowns, but the percentage of dry matter reached a minimum value of twenty-one per cent. During June there was a definite increase in the fresh weight, dry weight and percentage dry matter of the crowns of all the plants. The greatest increase was shown by plants in the deblossomed series. The shoot development of the Spring-planted runners commenced at a later date and was considerably less vigorous than that of the September-planted plants.

From the data recorded and discussed above it seems that the most rapid development of roots generally follows an earlier increase in the crowns. In the case of the normal cropped plants increase in the root system was recorded approximately one month after the increase in the shoot. In the deblossomed series this difference is much less marked. The rapid growth of the root system of the spring plants follows a period of increase in the crowns. Generally speaking root growth becomes most active after the normal cropping period, namely about the middle of July.

VI.—THE POSSIBLE PRACTICAL APPLICATION OF THE RESULTS OBTAINED SO FAR.

The observations which have been made on the season of root growth and on the point of origin of the new main roots would seem to indicate at least the time of the year at which root growth might be assisted or at any rate not hindered. The most vigorous growth of new roots had commenced by the beginning of August, that is to say by about one month after cropping. This points to the value of cleaning the strawberry rows as soon as possible after cropping in order to avoid disturbance of the new root growth. In addition, severe exposure of the crown should at all times be avoided, since it is bound to be prejudicial to root growth, the new roots having been seen to have their

origin markedly above that of the older ones. Conversely it seems likely that root growth might be assisted by a slight moulding up of the plants after cropping, however, no recommendations will be made on this point until it has been tested out in the field. Observations made in the field confirm this view of the value of close proximity between soil and crown, plants with exposed crowns being poor in vigour and often having undersized leaves. This has long been recognised but is often forgotten. In 1881 Thompson wrote in *The Gardener's Assistant*: "If the stem of any strong growing sort be taken and the lower leaves stripped off, it will be seen that there are a number of white points ready to push, if circumstances should be favourable for their doing so. They do not push through the coatings formed by the bases of the leaves above ground, but if the stem is buried in soil, or in a good top-dressing of rotten dung, leaf mould, or even leaves, they will strike root, in consequence of which the plants will be greatly invigorated. . . ." Our own observations fully confirm this.

In addition the possible beneficial action of an application of some fertiliser after cropping is to be tested.

VII.—OUTLINE OF FURTHER WORK PROPOSED TO BE CARRIED OUT IN THE ENSUING SEASON.

As stated above the writers deem it necessary to confirm the results which have so far been obtained by more than one season's work in order to ascertain something of the likely seasonal effect on the normal shoot and root growth of the strawberry. In addition, at the commencement of this article it was stated that the effect of soil and climate would also be investigated, and that examination of plants would be carried out until three years after the date of planting. The results so far obtained suggest points the application of which should be tested. Hence the following programme of future work has been decided upon and will, of course, be enlarged as occasion arises.

The runners planted in September, 1924, and in the Spring, 1925, will be examined at intervals for two more seasons. In addition, observations will be made on the deblossomed plants for one more year. Runners planted in August, September, October, and in the Winter of 1925 and in the Spring of 1926 will be examined for at least two seasons, and in addition runners planted in Norfolk in September will be examined concurrently. The method-of-planting experiments have been repeated. The effect of earthing up, and of drawing the soil away from the plants, and of damage to the crowns and to the roots at different seasons of the year will also be examined.

SUMMARY.

1.—The normal root and shoot growth (excluding foliage and fruit) of the Strawberry during the first year from planting is described.

2.—Vigorous shoot growth usually precedes root growth. Little growth of the root system is observed in Spring. The most vigorous increase in the root system occurs in the late Summer and Autumn.

3.—The new main roots, which develop after cropping, arise from the lower portions of the new crown growth and from $\frac{1}{2}$ to $1\frac{1}{2}$ inches above the older roots. These new roots appear in groups of from one to three to the right and left of the leaf bases of the older leaves on both the main and branch crowns.

4.—The effect of deblossoming was to increase the general vigour of the plant in both root and shoot. The deblossomed plants were less severely checked by the June drought than were the cropped plants.

5.—The effect of Spring-planting is also described for the early stages.

6.—Quantitative data confirm and amplify the qualitative observations.

7.—There is some evidence from the quantitative results obtained that the roots of the Strawberry may function as storage organs.

8.—The possible practical application of the results so far obtained is briefly discussed.

9.—An outline of further work proposed is given.

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PLATE I.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

PLATE III.

FIG. 1.

FIG. 2.

FIG. 3.

(a) (b) (c) (d)

FIG. 4.

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1.—Normal Series. Photographed on October 13th six weeks from the date of planting. The arrow indicates the position of the new primary roots developed since September 2nd.

Fig. 2.—Normal Series. Showing the condition of the plant in the dormant season. Note the large bulk of the root system in comparison with the bulk of the " crown " or shoot.

Fig. 3. Normal Series. Condition of the plant in the flowering season.

Fig. 4.—Normal Series. Condition of the plant after cropping. The arrows indicate the lateral buds which develop into daughter crowns.

Fig. 5.—Deblossomed Series. Compare with Fig. 4 and note the increased vigour of the crowns in the deblossomed plant.

PLATE II.

Fig. 1.—Normal Series. Condition of plant twelve months after planting.

Fig. 2.—Normal Series. Showing the amounts of older roots (left) and new roots formed since cropping (right) from five plants.

Fig. 3.—Deblossomed Series. Compare with Fig. 1 and note the increased vigour of this plant.

Fig. 4.—Deblossomed Series. Compare with Fig. 2 and note the large proportion of new roots developed since midsummer.

PLATE III.

Fig. 1.—Spring-planted Series. Condition of the plant in September. Compare with the normal plant (Plate II., Fig. 1).

Fig. 2.—Spring-planted Series. Showing amounts of older roots (left) and new roots formed since midsummer (right). Compare with normal plant (Plate II., Fig. 2) and note the greater bulk of new roots.

Fig. 3.—This photograph (July 20th) shows the points of origin of the new roots which develop after the cropping period.

Fig. 4.—Illustrates the types of roots found on a one year old plant.

(a) Root developed after midsummer. Note these roots are as yet only partly furnished with lateral roots.

(b) Root developed in Spring. This root is completely furnished with new lateral roots.

(c) Root developed in the Autumn soon after planting. The cortex is now dead and brown and few of the lateral roots remain.

(d) One of the original runner roots showing the production of lateral roots from the damaged main root. The finer lateral roots have died.

THE IMPORTANCE OF APPLIED BIOLOGY IN MODERN FRUIT GROWING.*

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The task of the modern fruit grower is not limited to overcoming the difficulties connected with the growing of the crop or to removing obstacles which depress the yield, for he has to deal with factors that interfere with the quality of the crop or that affect the crop in storage. The factors in most instances are of a biological nature and unless expert biological advice is ready to hand the grower's chance of success is severely handicapped. Some diseases are so severe in their action that the crop is reduced below the economic limit, as in the case of Reversion and Big Bud in black currants, Red plant in strawberries, Weevil in apple blossoms ; whilst in others the life of the plant itself is threatened, as in the case of plum trees attacked by Silver Leaf, pear trees attacked by Fire Blight, and even fruit trees and bushes attacked by Brown Rot. There are plant parasites which suck the sap and drain the vitality of the plant down to a low ebb. No modern fruit grower can afford to tolerate indifference to these types of pests, but has to bring the science of biology to his aid to diagnose the organism and to define the method for its control.

Applied Biology in cases such as these has been of so much assistance that further elaboration is unnecessary. Before, however, dismissing the subject entirely it would appear that as a result of field experience some biologists are changing their ground to some extent in that the presence of the organism is recognised as due to conditions detrimental to the host which in impaired health succumbs to disease. Professor Brooks in his recent paper on Silver Leaf seems to accept the presence of the spores of the organism in many orchards, and has attempted to find out the conditions which make it possible either for the tree to resist the entry of the disease or for infected trees to emerge triumphant in their fight for life against the parasite. To quote another case—Britton-Jones, of Long Ashton, has declared that diaportha—the cause of death in many plum trees—is a common and resident pest in most old orchards, but by pot experiments conducted at Long Ashton, he showed that the disease was incapable of doing much damage where trees were growing well under properly fertilised conditions, but that it completely killed those trees of poor growth and somewhat starved of fertilisers. Professor McLean Thompson has shown that ripe unsterilised oranges may be kept for five months provided the conditions are such that the vitality of the fruit is not impaired, but that as soon as the atmosphere becomes

* This paper was read before the "Association of Economic Biologists" on the 26th February, 1926.

impure the vitality drops to a low ebb, penicillium mould becomes manifest and decay follows.

The writer's knowledge of entomology and mycology is too limited for any deduction of much value to be made, but it does appear to a practical mind that this changing of the ground is not without importance, for it widens the scope of activities of the applied biologists, and it opens the way for the field-trained mycologist to render greater assistance to fruit growing. It may be a little disconcerting for the first-class honours B.Sc. in Mycology, who is perhaps a walking Encyclopædia of the life histories of all fungal organisms, to realise his helplessness in dealing with field cases until after a further period of training and observation work in soils, manures and plant growth; but there is the consolation that at the end comes the realisation that Applied Biology is a life science playing a real part in protecting and increasing the food crops of the country. The dictionary definition of biology is "the science of life," and I would add that in so far as *Applied Biology* is concerned, it must be the science of the life of the host as well as the parasite and of the conditions beneficial or detrimental to the health of the host.

Passing now to the second part of the paper an attempt will be made to show how the change in the demands of the present population has compelled the fruit grower to lean more and more on the biologist in his endeavour to produce the class of fruit in demand. The apples in demand at present in this country are those of good appearance with *clean bright skin, free from blemish—large size and flesh quality are also of importance.* Those growers who have grasped this awful truth see that the fashionable apple can only be obtained from clean orchards where diseases which blemish, or pests that injure the fruits are rigorously kept under control. Neither Scab, Aphis, Codlin Moth nor Capsid Moth can be tolerated, and Applied Biology must take a hand in devising measures of control. Perhaps it is best to illustrate this point by instances as they occur in practice. In Nova Scotia where large quantities of apples are grown for export to the markets in this country, growers are not able to produce fruit all of uniform size and quality, and in order to realise the best prices a system of grading prior to packing in barrels has been adopted. Grading for barrel packing is largely a matter of a differentiation in size and colour, though pests damage constitutes a serious defect and prevents such fruit from being sold in the top grades. The growers have agreed to the kind of apple for each particular grade and have persuaded their respective Governments to legally define these by Act of Parliament, in what has become known as The Canadian Fruit Act. The grades for the barrel apples are known as No. 1, No. 2, Domestic, and No. 3.

No. 1 *Grade* shall include only well-grown hand picked specimens of not less than medium size, and . . . not less than ninety per cent. free from scab, worm holes, bruises and other defects.

No. 2 Grade shall include only hand picked specimens of not less than nearly medium size . . . sound and not less than eighty-five per cent. free from scab, worm holes, bruises and other defects.

Domestic shall include only hand picked specimens of not less than medium size for the variety, sound and not less than ninety per cent. free from worm holes (but may be slightly affected with scab and other minor defects).

No. 3 Grade shall include only hand picked specimens, no culls, and shall be properly packed.

It will be observed that according to the grades apples blemished to any appreciable extent cannot be sold as Grade 1 or Grade 2, but must be placed in the Domestic, or still lower in Grade 3, which may mean a considerable loss to the growers. About thirty per cent. of all the crop in Nova Scotia is marketed co-operatively through one organisation, The United Fruit Companies of Nova Scotia, and from this Company the writer was able to ascertain that for the season 1923-1924 the following quantities were sold in the English markets at the following prices:

108,340 barrels of No. 1 grade realised gross £122,268 18s. 10d.; Av. 22s. 7d.
81,749 barrels of No. 2 grade realised £79,609 0s. 3d. Av. 19s. 5½d.
53,751 barrels Domestic grade realised £51,228 10s. 9d. Av. 19s. 3d.
77,589 barrels of No. 3 grade realised £58,818 17s. 0d. Av. 15s. 2d.

The figures clearly illustrate the smaller commercial value of the blemished fruits sold as Domestic or as Grade 3.

Dealing with the matter in more detail, the 487,142 barrels handled by the United Fruit Companies of Nova Scotia in 1923-24 gave prices which averaged for each variety as follows:—

Variety.	*No. 1.*	*No. 2.*	*Dom.*	*No. 3.*
	$	$	$	$
Baldwins	3.34	2.48	2.47	1.21
Ben Davis	3.07	2.15	2.32	1.19
Blenheims	2.73	2.18	1.93	1.02
Gravensteins	3.17	2.76	2.48	1.51
Kings	3.31	2.77	2.45	1.66
etc.				

The apples of Grade 2 are smaller in size and less fully coloured than those of Grade 1, though both should be practically free from "pest" injury. Blemish and pest injured fruits—if the damage is slight—can be sold as Domestic grade, otherwise they go with the culls to the Fruit Products factory and are turned into canned apples, dried apples, cider or vinegar. The difference between the

Price of Grade 1 fruit and the Domestic Grade is a measure of the part of the loss caused by disease. The growers have no option in this matter, for the skilled graders in the packing work to the rules without fear or favour.

In Nova Scotia there is a very troublesome disease, popularly known as "Ink Spot," because that is just how the spots of its sooty spores look on the skin of the apple. Scab is also prevalent and the usual insect pests abound. Both the State Government and the Federal Government are interested in providing advice of a biological nature for entomologists and mycologists reside in the fruit areas to render assistance. Their co-operation with the growers has been successful, as instanced by the fact that most growers spray three or four times and the best five or six times.

The first spray consists of lime-sulphur of 1.009 specific gravity, or 3 gal. commercial strength to 100 gal. water (1 to 33), with the addition of arsenate of lime 2 lb. to 100 gal. This is put on at 200 lb. pressure when the trees are in the green bud stage. For the second spraying, just before the blossom buds have opened, weaker lime-sulphur (1 to 43) and arsenate of lime is used. The third spray, after the petals have fallen, consists of lime-sulphur 1 to 50 and arsenate of lime 1½ lb. to 100 gal. Two weeks later the fourth spray is used and this consists of Bordeaux mixture (7 lb. copper sulphate, 7 lb. quicklime to 100 gal.), with 5 lb. paste lead arsenate added to each 100 gal. In very wet seasons a fifth spray, similar in material to the fourth, is used two weeks later to control apple scab.

The advantage of spraying was well illustrated by the following figures taken from the books of the Packing Station at Fort William :—

Grower A (trees sprayed six times) and total Gravenstein crop graded in 1924, as follows :—

76% Grade 1.
14% Grade 2.
7% Domestic.
3% Grade 3.

Grower B. (trees said to only spray twice) sent in 458 barrels, which gave only 130 barrels Grade 1.

In the Western States of North America the fruit trees grow high up on the slopes of the Rockies, where the atmosphere is both hot and dry, so that resort has to be made to artificial irrigation to bring down the snow water from the mountains to the trees. Fungus diseases are not too troublesome, but bacterial diseases and insect pests are an even greater nuisance than in this country, for species like the Codlin Moth have more than one brood in the year, and spraying has to be continued late into the season.

The majority of growers are members of or belong to Societies, Associations or Fruit Unions, and these own packing houses and storage chambers into which

the fruit passes for grading, packing and storage before marketing. After grading the fruit of each grower loses its identity and goes to make up bulk consignments, so that the process of payment is based on what is known as the "pool" system. A pool is made usually for each of the leading varieties, which means that the total packages of each grade are obtained and also the figure of the total amount realised of each variety; then by a simple piece of arithmetic an average figure for the top grade is obtained. The allotment for the lower grades is made on a lesser scale.

The apples are packed in boxes, for which the grades are:

Extra Fancy Grade shall include only firm, mature, clean, smooth, hand picked, well-formed, fruits of good colour for the variety, free from *all insect pests, diseases, bruises, spray burns*, limb rub, visible water-core, skin punctures or skin broken at the stem.

Fancy Grade shall include only firm mature fruits of one variety of fair colour for the variety, and free from all insect pests, diseases, spray burns, etc.

C. Grade shall include only fruit free from infection, soft bruises and broken skin, provided that this grade may include healed over stings and scab spots not to exceed one half square inch to the aggregate.

It will be observed that the fancy grade differs from the fruits of the extra fancy grade, in that the colour is of a less standard; fruit damaged by pests can only appear in the lower C grade or if appreciably damaged they go into the Cull Class.

The crop grown in British Columbia in 1923-24, grading, as follows:

		No. of Boxes.		*Average price.*
Extra Fancy.	Large	561,129 or	22.53%	1.10$
	Small	222,184	8.92%	.93$
Fancy	Large	571,747	22.96%	1.01$
	Small	134,915	5.42%	.99$
C. Grade		54,035	2.17%	.91$
F. & C.		293,172	11.77%	.92$
Economy Crates		653,243	26.23%	.70$

The difference in price between the extra fancy large and extra fancy small, is a measure—perhaps not an accurate one—of the value attached to the size by the Canadian and American public.

The fancy large and fancy small are sold extensively in the English market, where, as the smaller difference in price shows, size in a dessert apple is considered of lesser importance.

The difference in price between say the extra fancy large and the fancy large is a measure of the colour value for the same varieties of apples as expressed by the consuming public. The price of the C grade fruits and those in economy

crates is on a much lower standard and as the depression in price is due almost entirely to blemishes caused by insect and fungus pests, one is able to see some of the great losses that these pests cause.

The grower has no hand in this matter for the work of grading is done by the staff at the Packing Station. Each grower's fruit is graded separately and the grower is handed a sheet showing how the fruit has graded, together with remarks concerning pest damage. These sheets are of great value for, as one grower said, the sheets give the record of culture and show where improvements should be made. If there are too many small fruits, more water and more manures should be applied ; if too few extra fancy grade, the trees need thinning ; if too many blemished fruits, more spraying should be done. This same grower informed the writer that by watching the grading records and by spraying and manuring, etc., he had improved his methods and produced in 1925 a crop that graded into 96% Fancy or Extra Fancy fruit [96% free of pest damage], 3% C grade, and 1% Culls. In the dry atmosphere of British Columbia fruit diseases are of less trouble than insect pests, so the entomologists, both State and Federal, of whom I met several in the district, are kept busy giving advice.

The figures from the Packing Stations show the growers in a direct form the superior market value of clean fruit over blemished fruit, and though they may not fully realise their dependence on Applied Biology, are ready to spray three, four, five and even six times.

In California, where the organisation of modern fruit growing is most advanced, the writer is told the Californian Fruit Growers' Exchange employs experienced Entomologists, Mycologists and spraying teams, which are sent out in the orange fields to conduct the pest control work in cases where the efforts of the growers are unsuccessful in producing *clean* and *unblemished* fruits. In these parts, pests which affect the trees or injure the blossoms are not considered of the same importance as those which *injure or blemish the fruits, and it is against this class that war is waged.*

As vast quantities of these fruits from all these places are sold in the British markets, it is a fair assumption that the British grown fruits, when marketed, experience this great differentiation in value—though in the absence of recognised grades for home-grown fruit the growers have not realised so fully the great selling value of *clean* fruit and the low *value* of even slightly blemished fruit, to say nothing of the comparatively valueless culls. In England apple packing houses have been established at Cottenham (Cambs.) and at East Peckham, and Faversham in Kent, whilst private companies and individuals have in other places.

The work at the Cottenham Packing Station, which was set up in 1924 by the Ministry of Agriculture, was controlled by Mr. Turnbull, who informs the writer that of the grade sent out the Extra Fancy contained unblemished fruits. The

fruit in the fancy grade may have had slight blemishes, whilst that in C grade may have been generally blemished in some way. Consignments too much blemished were sold in bushel baskets as seconds. The crop sent to the Station graded out as follows :

Dessert varieties.		*Culinary varieties.*	
Extra Fancy Grade	2 boxes.	Extra Fancy Grade	548
Fancy Grade	126 ,,	Fancy Grade	1,175
C Grade	413 ,,	C Grade	851
Culls	218 ,,	Culls Grade	252

Owing to the season of 1924, the poor and small crop delivered was said to be much below the standard of crops for normal years, and therefore any deduction made must be of limited value. It will be noticed at once that the quantity of unblemished dessert fruit was exceedingly small ; it was higher for culinary kinds, but even these formed but a small percentage of the total bulk. After packing the fruit was handed back to the growers to send to the market, so the Station is unable to give any figures to show the price at which the different grades of fruit were sold, though the writer is informed that the prices for the Bramley Seedling variety averaged over the whole season, were 9s. 6d. per box for extra fancy, 8s. 1d. per box for fancy, and 3s. 6d. per bushel basket for seconds.

If these prices are combined with some of the grading figures given above an idea can be gained of a part of the financial losses caused by pest damages. It may be useful to record that the dominating defect of the culled fruits and the fruits passed to C grade was " scab." There was a proportion of the fruit showing caterpillar damage and injury by Capsid Bug, but " Scab " blemishes were responsible for over ninety per cent. of the low grading.

The Packing Station at East Peckham in Kent, in 1925, received samples of Quarrenden of good size and well coloured, but so blemished with " scab " spots that in one consignment there was not sufficient of unblemished fruits to fill a box. On the other hand the best consignment received at this Station was of the variety Beauty of Bath, and this graded into 84% Extra Fancy, 14% best grade in half sieves, and 2% of seconds and thirds. Adding the figures of all the consignments for 1925 together it appears that of all the apples sent in to the East Peckham Station, a low proportion only were suitable for packing in boxes, the exact proportion for some varieties being : Beauty of Bath 40%, Worcester Pearmain 22%, Cox's Orange Pippin 18%, Hunt's Early 27%. Mr. Gregson, the Director of the Station, says that the dominant blemish found on the apples at this Station was " scab." It was common on all varieties except Beauty of Bath, and caused thousands of bushels of large well-coloured apples

to be sold as seconds and thirds, in barrels, instead of as extra fancy and fancy, in boxes.

The successful storage of apples, of which space will not permit me to write, has now become a practice based on science, so that whether in protecting the tree, or safeguarding the crop, both on the tree and in storage, the grower is compelled to base his practices on scientific knowledge, or the chances are that the results will be failure. If the trees or the crop on the trees are neglected, the fruits may become diseased or blemished and lose most of their commercial value. The demand is for clean, unblemished fruit and that can only be produced by fruitgrowers willing to make the best use of the knowledge that science has provided.

INFLUENCE OF SUMMER RAINFALL AND PREVIOUS CROP ON FRUITING OF APPLES.

A. H. LEES, M.A., Long Ashton.

Introduction.

The factors that favour fruit production have long been a matter of speculation among fruit growers and others and in their widest sense may be said to be fruit growing itself. Of this large subject, however, the writer desires to review certain aspects only to which perhaps but scant attention has been paid so far. It is, of course, a fact familiar to those interested in fruit growing that a large crop in one year tends to be followed by a small crop the next year, though it is also obvious that exceptions occur at fairly frequent intervals when two large crops are produced in two consecutive years. A fact also familiar, but perhaps less so, is that a dry summer tends to give a better crop in the following year than does a wet one. To this too there are exceptions, unaccountable if taken alone, but understandable, as the writer has endeavoured to show in this paper, if taken in conjunction with the previous crop. Pathological factors are of course frequently of the utmost importance but for the purpose of this paper with the exception of aphis their influence is neglected and the tree considered healthy. Though many of the facts stated below will possibly be found to have a bearing on many, if not all, fruits it is proposed to confine this discussion to the apple.

Before considering the experimental data on the influence of summer rainfall and previous cropping on subsequent crops, it is desirable to examine some of the conceptions of the conditions necessary for fruit production. For this purpose the subject has been treated under the following headings : (1) The normal phase of growth, (2) Current conceptions of the factors necessary for cropping in apples including (*a*) Flower Production, (*b*) Spring Weather, and (*c*) Previous Crop.

The Normal Growth Phase of the Apple (1).

The early activities of those parts of a young apple plant which are above the ground are mainly confined to the production of wood shoots. As the years go by, however, the plant has an ever increasing tendency to form spurs which may or may not bear flower buds. As it reaches what is, for it maturity, the production of spurs becomes abundant and the production of wood shoots of small importance.

If a single shoot of last year's growth be examined in the spring it will be noticed that the buds are developing at an uneven rate. Roughly speaking

the terminal bud shows the most active growth and the basal the least. So weak indeed are the basal buds that frequently they remain completely dormant. At a somewhat later stage, say in late May, it will be found that though the apical three or four buds are still actively growing and producing long shoots the other buds have stopped. They have, in fact, produced various types of spurs. Roughly speaking therefore two kinds of growth can be seen, shoot growth and spur growth. With comparatively few exceptions flowers in the apple are only produced on these spurs. The spurs borne on a given year's growth vary however in strength. Just as the basal buds were originally weaker so the spurs developing from them are weaker. So weak are they (as shown by their sessile position and few leaves surrounding the bud) that it may be years before they attain sufficient strength to flower. Those nearer the apex are stronger and may flower next year while the nearest may be so strong that their axis is three or four inches long and their terminal a wood bud and not a flower bud. There is, therefore, a distinct gradient in strength ; the weakest are too weak to form flower, the medium are just in the right condition, while the strong do not cease growth in length soon enough in the season to store sufficient food for flower production.

The state of the tree as a whole has a big influence on the general reaction of these spur units. If the tree is young and vigorous or is stimulated by hard pruning or liberal manuring it tends to produce a large number of the extra vigorous spurs which, indeed, in these cases do not cease growth early in the season, but become definite wood growths. Under the reverse conditions however true spur formation is increased markedly and the tree takes on the mature, or semi-mature condition. It then becomes a mass of spur growths borne on the frame work of the tree. Some of these spurs may have flower buds and others leaf buds. It is no longer a question of forcing conditions producing wood growth and checking conditions spur growth ; spurs are produced in either case.

When the flower bud on a spur opens, its axis elongates and bears at its tip the flower organs. Soon that portion of the end of the axis bearing the flowers thickens and forms the so-called " bourse " or knob. On this knob are borne laterally, on opposite sides but at different levels, two growing points. These are of the utmost importance to the future cropping of the tree since they form the possible supply of future flower buds. They may take one of three different directions in their subsequent development. They may remain small leaf buds or they may form flower buds with a shorter or longer axis or they may grow out into shoots. Which of these courses they take depends on the same conditions that regulate shoot and spur production in the adolescent tree. The continuous production of flowers from bourse buds year after year is of course the first essential for continuous, as distinct from biennial fruiting.

CURRENT CONCEPTIONS OF THE FACTORS NECESSARY FOR CROPPING IN APPLES.

(*a*) *Flower Production.*

Perhaps the most commonly looked for sign of a future crop is an abundant flower production. "Well ripened" wood is considered favourable for flower production. It is difficult to get a definition of this phrase from the grower, but the essential point appears to be that the wood should cease growing in length at a fairly early date. For apples this would be about the end of July. The wood also should have pronounced secondary thickening and should be of a plump appearance. When these conditions are obtained the spurs on the older wood are also well formed. That flower production is an essential is of course obvious, especially since pomologists have shown that frequently, but one in seven or one in ten flowers will set. (3)

Most fruit growers, however, are well aware that the weight of crop is by no means proportional to the number of flowers produced in the spring. It becomes necessary to distinguish between a strong bloom and a weak bloom though, here again, it is difficult to obtain a definition. Usually, however, a good bloom has larger petals and flowers and comes out earlier than a weak bloom. This point of relatively early opening of the strong flower does not appear to have been pointed out. Usually it is considered that the late opening flower is more likely to set than the early opening flower, since it would escape inclement weather. It is, however, easy to convince oneself by simple observation that this is not so. The first flowers to come out in spring are those spur flowers situated in a "strong" position, namely near the pruning cut of two years ago. These are the spurs which produce large flowers and which have the greatest tendency to set, often several to the truss. Those in a "weaker" position, namely nearer the base of the year's growth, are later and smaller and often fail to set. It is an abundance of such "weak" flowers that give the extraordinary show of bloom seen in some springs, a bloom, however, which usually fails to materialise in a heavy crop.

(*b*) *Spring Weather.*

The second important factor that the grower usually looks for is the character of the spring weather. Frosts are feared by all, but some have gone a step further and recognise the danger of continued cold winds. It is the contention of the writer that the danger of spring frosts has been greatly overrated except in certain situations which, from the aspect of the land, form a natural drainage for cold air. A striking example of a severe frost followed by a heavy crop at Evesham is cited below.

The danger of cold winds is probably a more real one, but since such winds in spring are usually of the dry north-easterly type it is possible that a long, continued period of dryness is as important in this respect as low temperature.

(3) *Previous Crop.*

It is a commonplace among fruit growers that a glut crop is followed by a very scanty one. The unfortunate grower frequently finds himself as a result between the scylla of large crops and low prices and the charybdis of negligible crops and high prices. This state of affairs seems to be accepted as a sort of providential arrangement which cannot be altered. The trees are said to require a rest and cannot be expected, apparently, to bear continuous crops. That this state of affairs is not necessarily a law of nature can be seen from such fruit plants as the logan, which normally crops every year without fail. Even apples may be made to crop as many as five years continuously provided they are of a naturally good bearing habit, as in the case of Worcester Pearmain and Allington Pippin. To obtain this result, however, it is necessary to take special measures with regard to pruning and manuring, which subjects do not enter into the scope of this paper.

THE INTERNAL CONDITION OF THE TREE.

It is the writer's contention that much more attention should be given to certain factors apparently necessary for fruit production in apples. Too much weight has been put on some factors, such as the character of the spring weather and too little on others, such as the internal condition of the tree. This factor seems indeed to outweigh all the rest in importance, so that given the proper internal condition, spring frosts, unless very severe or long continued, can be endured with impunity. A remarkable example of this occurred in the plum crop in Evesham about fifteen years ago. When in full bloom a snowstorm occurred which covered the flowers completely. Later in the day this partially melted and towards night froze again. All night the blooms were locked in ice and dire prophecies were made of failure. Actually however a heavy crop was set, because the internal condition of the trees was correct.

A correct internal condition expresses itself firstly in the formation of flowers and secondly in the strength of such flowers. As pointed out earlier in this paper the mere production of flowers is no criterion of a crop ; they must be strong vigorous flowers which, although they open relatively early, have the right internal condition for cropping. Such flowers can be only formed if the general organic reserves are found in the right place, namely, near the spurs. There appear to be two distinct factors at work here, the amount of reserves and the placing of them. For the production of reserves raw material in the form of manure must, of course, be abundantly supplied to the leaves for further manufacture. When once this organic food is formed it may be used in various ways.

(1) It may feed the crop of apples.

(2) It may feed the extending shoot system.

(3) It may feed the extending root system.

(4) It may be laid down as general reserves, especially near the spurs.

Which direction is actually taken appears to depend on two important factors, the "crop factor," and the "water factor." By the "crop factor" is simply meant whether the tree is bearing a large, moderate or small crop, or none at all. It is quite clear that, in ordinary conditions of fruit growing, when a crop is set it has a considerable pull on organic foods available through the plant's activities. So much is this so that it is recognised that the presence of a large crop causes much less extension wood to be formed than when no crop is borne, other things being equal.

The "water factor" is a more complicated one. The following conditions, however, tend to increase it; hard pruning, abundant manuring, strong root stocks and moisture in the soil and in the air. In short everything favouring root action, especially root action in relation to the above-ground portion of the plant, causes a high "water factor."

The result of a high "water factor" however produced, is to cause strong extension growth whereby organic food is used up in the process of forming new wood. According to Kraus and Kraybill (2) such a tree has a low carbon-nitrogen ratio and this state is associated with infertility. The work on this aspect has been recently surveyed by Hooker (4). The most reasonable explanation is that but little organic food is left over as a reserve near the spurs during the late summer and possibly through the winter.

Should there be no crop or a light crop and the "water factor" be low (as when dwarfing stocks are used, the manuring is not excessive and the pruning is light), and more especially when the summer rainfall is low, then the organic food reserves must go either to the spurs and adjacent storage tissue or to the roots. They cannot go to make extensive growth or to feed the crop.

In mature or semi-mature apple trees pruning is no longer an important factor and the stock is constant so that, eliminating the effect of manuring which is outside the scope of this paper, the chief factors out of those considered above which determine the crop for the following year are :—

(1) Presence and amount of crop in the current year.

(2) Rainfall during the summer.

Experimental Data.

In order to examine the relation of these two factors with the crop production for the following year data for summer rainfall and cropping has been obtained for as many years as possible at two distinct centres, namely Long Ashton and Woburn. The important months for rainfall have been considered to be June, July and August. The reason for selection of these months is that

during June from figures obtained at Long Ashton in 1919 the growth rate of apples appears to be at its maximum, and the soil humidity during July and August appear to exercise a controlling influence on the date when growth in length ceases. It is not until this event occurs that organic food can be placed in large quantities as reserve for formation of flower and fruit for the following year.

Long Ashton Rainfall.

These figures go back to 1853 and extend to 1925. From 1853 to 1872 they are obtained from the official figures for South Parade, Clifton, from 1873 to 1907 from similar figures for Pembroke Road, Clifton, and from 1908-1925 from figures recorded at the Long Ashton Research Station. The overlapping years in the record for the first two stations namely 1873 to 1891 show that the difference between these stations for these years is but a negligible one and therefore the period 1853-1907 is fairly covered by a combination of the two data. A similar argument applies to the union of the Long Ashton with the Pembroke Road figures from 1908-1925.

Long Ashton Cropping.

It has been impossible to obtain satisfactory figures for actual cropping for Long Ashton itself. Such figures could be only reliable if obtained from a mature orchard of sufficient size. The official description of the crops for Devonshire, Somerset and Cornwall, however, serve perhaps a more useful purpose, since the effect of manuring, stocks and other interfering conditions are thus automatically cut out.

Woburn Rainfall.

The figures for the June, July and August rainfall here extend from 1895-1919 and were all obtained at the Woburn Experimental Station.

Woburn Cropping.

The figures extend from 1899, when cropping was definitely beginning, to 1920, when the station was closed. The figures are the sum total of separate ones obtained from the following plots :—Bramley Dwarf Plots 1-11 and 22-41. Bramley Standards Plots, 189-200. Stirling Castle Plots, 181-188. Also from Farmers' A and B Plots, Growers' A and B, and Cottagers' A and B Plots. All plots were included except those, where, owing to drastic experimental treatment, the figures would probably be misleading.

METEOROLOGICAL OBSERVATIONS.

The rainfall figures in Table I. referring to the sum of the monthly totals for June, July and August, extend over a period of seventy-three years. The corresponding graph (I.) shows a series of peaks and valleys fairly regularly

distributed. Taken as a whole a peak is usually quickly followed by a valley, though not necessarily in the following year. Often the graph takes two years to reach a lowest or highest point, but nevertheless there is a strong tendency for a wet to be followed by a dry year and a dry, by a wet year. This tendency suggests one reason why a young apple may be switched into the biennial bearing habit. If a dry year comes there is a considerable reduction in the "water factor" which, as shown above, induces the flower habit. The following year a crop is borne and this, if combined with a wet June-August period

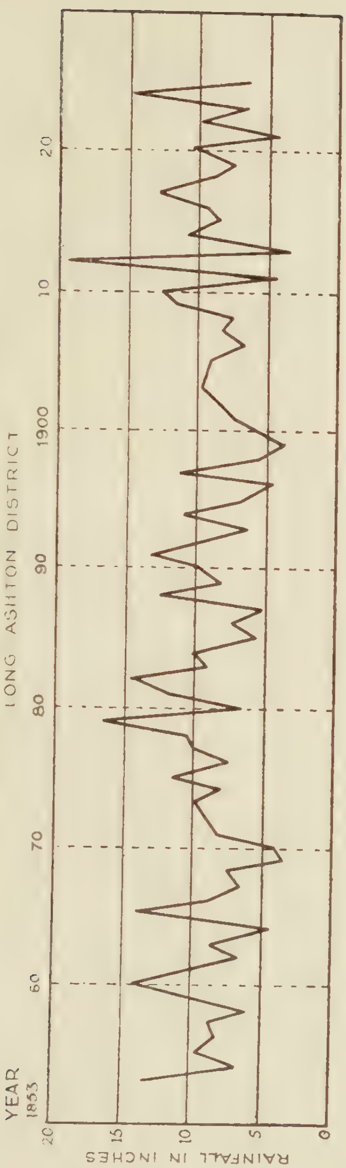
TABLE I.

Total Rainfall for June, July and August (inches).

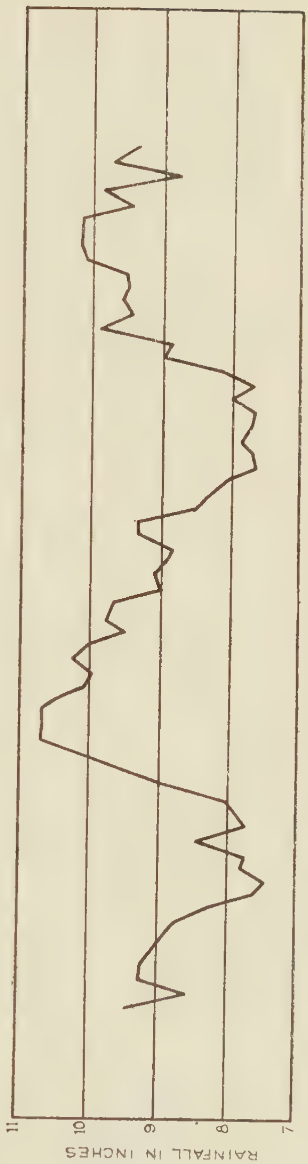
Long Ashton District.						Woburn.	
1853	13.67	1878	10.21	1902	8.60	1895	7.55
1854	6.94	1879	16.82	1903	9.88	1896	5.18
1855	9.91	1880	7.89	1904	9.55	1897	6.13
1856	8.10	1881	11.97	1905	9.30	1898	6.90
1857	8.58	1882	14.79	1906	6.72	1899	3.40
1858	5.98	1883	9.32	1907	8.29	1900	7.85
1859	9.82	1884	10.16	1908	7.52	1901	5.58
1860	14.65	1885	5.30	1909	11.49	1902	7.60
1861	10.04	1886	7.73	1910	12.87	1903	12.14
1862	6.71	1887	5.32	1911	4.50	1904	5.41
1863	9.04	1888	13.02	1912	19.12	1905	7.50
1864	4.24	1889	8.23	1913	3.72	1906	5.32
1865	14.32	1890	9.98	1914	11.04	1907	5.88
1866	9.54	1891	13.34	1915	8.42	1908	4.99
1867	6.85	1892	9.61	1916	9.84	1909	9.40
1868	7.28	1893	7.31	1917	13.26	1910	5.69
1869	3.39	1894	11.02	1918	9.32	1911	3.64
1870	4.09	1895	7.76	1919	7.71	1912	10.35
1871	8.42	1896	4.45	1920	10.49	1913	2.85
1872	9.32	1897	11.42	1921	4.33	1914	5.11
1873	9.93	1898	5.49	1922	10.11	1915	7.54
1874	8.04	1899	3.66	1923	6.60	1916	6.72
1875	11.63	1900	5.84	1924	15.05	1917	11.18
1876	7.30	1901	7.42	1925	6.48	1918	5.53
1877	10.09					1919	6.65

increases the "water factor" and uses up reserves, thus preventing flower formation for the next year. The tendency is therefore to cause biennial bearing.

Whereas in most parts of the graph this up-and-down tendency is seen, there are two points, from 1869-78 and 1899-1910, where the graph is fairly smooth. This point is more clearly shown in the lower graph II., representing eleven year period averages. This period of years was taken owing to the well-known eleven year sun spot period. If a similar eleven year periodicity were taking place in the summer rainfall a straight line should be produced by eleven year averages. Actually, however, a different type of curve was obtained. A period of extra dry summers occurred round about 1870, and a similar one about 1900. Between



GRAPH I. TOTAL RAINFALL JUNE-AUG INCLUSIVE
LONG ASHTON DISTRICT



GRAPH II. 11 YEAR AVERAGE RAINFALL JUNE-AUG.

1870 and 1880, and to a less extent from 1900 to 1910, there is a continued sharp rise culminating in one case in the well-known wet period of the eighteen eighties, and in the other case to the less marked years of 1909, 10 and 12.

The graph suggests that there is a major periodicity of about thirty years. It is impossible to say whether this would really be thirty-three, namely three sun spot periods, but the closeness of the figures is suggestive. After attaining a general maximum there seems a tendency for a slow decline extending over twenty years or so. This can be seen from 1879-97, and parts of a similar curve from 1858-67 and 1915-25, though the latter is somewhat doubtful.

On the whole therefore there appears to be a general tendency for a ten years dry period followed by a twenty year period which is wet at first but gradually becomes drier. There is some suggestion, though not a marked one, that the next five summers will, on the whole, be drier.

The Relation of Summer Rainfall to the Succeeding Crop.

Long Ashton District.

It was pointed out earlier in the paper that after excluding pests, diseases and manuring the only remaining factors varying from year to year were weight of crop and summer rainfall. It is the writer's contention that when the apple crops over a large area are considered these two remaining factors determine the crop for the succeeding year. The evidence for this is shown in Tables II. and VI. the former referring to results obtained for Long Ashton district and the latter for Woburn.

In Table II. all the various factors are placed side by side. Column 2 contains the actual crops of last year (Ministry of Agriculture's description for Somerset, Devon and Cornwall). Column 3 contains the summer rainfall in inches and the indication of dry (D), medium (M), or wet (W) types. Less than six inches total is considered as dry, six to nine inches total as medium, and over nine inches total as wet. These figures are chosen not from any scientific standpoint, but simply because it is found from experience that a rainfall of under six inches total gives an impression of a markedly dry summer, and one of over nine inches of a markedly wet one. These conditions are also associated with an unusually dry and unusually wet soil respectively during the critical months, June-August. Column 4 contains the abbreviated description of apple blooming in the south of England from the reports of "Southern Grower" and "Market Grower," in the *Gardeners' Chronicle.* It has unfortunately been impossible to obtain such reports from the south-west to which the crop descriptions apply. There is therefore a possibility that, could such descriptions have been obtained, the results might have been slightly different, but they are as they stand exceedingly suggestive. Column 5 contains the actual crop experienced and

TABLE II.

Relation of Previous Apple Crops and Summer Rainfall to Flower Production and Crops of next year. Long Ashton District.

Year	Previous Crop.	Previous Summer Rainfall.	Flower Production.	Actual Crop.	Estimated Crop.
1906	..	..	..	Fair	..
1907	Fair	M (6.72)	..	Very short	Medium
1908	Very short	M (8.29)	Very good	Fairly plentiful	Good
1909	Fairly plentiful	M (7.52)	Well covered	Blighted, but fairly plentiful. A.	Poor—medium.
1910	Blighted but fairly plentiful	W (11.49)	Poor	Very poor	Poor—very poor.
1911	Very poor	W (12.87)	Very good	About average	Medium—good.
1912	About average	D (4.50)	Magnificent	Fairly plentiful	Good.
1913	Fairly plentiful	W (19.12)	Good	Very poor	Very poor—poor.
1914	Very poor	D (3.72)	Profuse	Abundant	Very good.
1915	Abundant	W (11.04)	Good promise	Poor. A.	Very poor.
1916	Poor	M (8.42)	Poor—very poor	Very short	Good.
1917	Very short	W (9.84)	Full of promise	Heavy	Good.
1918	Heavy	W (13.26)	Good and bad. Many leafy spurs	Small	Very poor.
1919	Small	W (9.32)	No remark given	Good	Medium—good.
1920	Good	M (7.71)	More than expected	Very small	Poor
1921	Very small	W (10.49)	Tremendous	Rather above average	Medium—good.
1922	Rather above average	D (4.33)	Big bloom	About average	Medium—good.
1923	Average	W (10.11)	Good show	Under average. A.	Poor.
1924	Under average	M (6.60)	Poor show	Below average	Good—very good.
1925	Under average	W (15.05)	..	Light	Poor—medium.

Rainfall. W—wet; M—medium; D—dry. Figures in brackets, June-August Rainfall in inches.

A—Excessive aphis attack in this year.

Column 6 the crop estimated by the use of Table III. This table contains an empirical scheme for working out probable crops for the following year. Following the arguments cited earlier in this paper, it is based on the reaction of the two factors (1) previous crop, (2) summer rainfall. The crops are divided into, heavy, medium, light and none, the rainfalls into wet, medium and dry. A special class is made for cases where no crop at all set owing to spring frosts. When this happens the following year's crop is almost certain to be good unless a second spring frost occurs. In the other cases the probable crop depends on the

TABLE III.

Scheme for Apple Crop Estimation.

Crop.	Rainfall.	Succeeding Crop.
Heavy	Wet	Very poor.
,, ...	Medium	Poor.
,, ...	Dry	Medium.
Medium	Wet	Poor.
,, ...	Medium	Medium.
,, ...	Dry	Good.
Light	Wet	Medium.
,, ...	Medium	Good.
,, ...	Dry	Very good.
None	Wet	Good.
,, ...	Medium	Very good.
,, ...	Dry	Very good.

reaction of the two factors. A wet summer and a heavy crop favour poor crops the next year, but a dry summer and a light crop favour a heavy crop the next year.

In view of the fact that for ease of working the scheme has to be made rather diagramatic the agreements between estimated and actual crop is fairly close. In certain cases 1909, 10, 11, 13, 19, 21, 24 and 25 as the factors come between two classes the corresponding estimated crop is similarly expressed.

There are certain well-marked exceptions to the estimates. These occur in the years 1907, 1916, and 1924. No explanation can be made for 1907, but the great reduction of crop over estimates occurring in 1916 and 1824 are quite obviously due to the overwhelming aphis infestation of 1915 and 23. The years

should have had "good" and "good—very good" crops respectively if only subject to rainfall and previous crop factors. The effect of the aphis was therefore very damaging to the next year's crop.

FLOWER PRODUCTION.

These descriptions, contained in Table IV. and put down shortly in Column 4 of Table II., though they come from the south instead of south-west, are very interesting when compared with the actual crop produced. It is, of course, well-known that a good bloom does not necessarily mean a good crop, and it is the writer's contention that certain combinations of the two important factors give a

TABLE IV.

Description of Display of Apple Blosson from "Gardeners' Chronicle."

1908	Apples very well furnished.
1909	Most varieties well covered.
1910	Some profuse, others small or none.
1911	Apples as abundantly supplied with blossom as they were poorly last year.
1912	The apple blossom was magnificent.
1913	On the whole a good display.
1914	Very striking profusion.
1915	Many varieties promising well.
1916	Poor to very poor.
1917	Nearly all varieties full of promise.
1918	Some varieties well furnished, some bare. Many spurs on opening proved to be leaf buds.
1919	No remark, apparently average.
1920	More bloom than expected after last year's great crop.
1921	The display of bloom is tremendous.
1922	Blooms even on one-year-old shoots.
1923	Good show, weather hindered development.
1924	Rather poor show.

heavy bloom followed by poor sets and heavy June drops. According to this hypothesis these poor sets and heavy drops are not due so much to unfavourable weather conditions following or present at flowering time, but to conditions occurring the previous year. In other words, it is the internal condition of the tree that is by far the most important point. The tree does not thin itself because it knows it cannot sustain its crop, but because the June drop is predestined. As an example of conditions under which, according to the popular theory, thinning, should have taken place, but did not, may be cited the plum crop at Evesham in 1911. An enormous crop was set and despite the extreme drought stayed on the trees, though the resulting plums were of so poor a quality that many remained unpicked.

Flowering in Relation to Cropping.

An inspection of Table II. shows in some cases that the crop is in strict proportion to the flower production, but that in other cases it falls far short. These later cases are examples of the well-known failure to set referred to above. The facts are made clearer if the cases are grouped. It is then found that extra good bloom are followed by only average crops when the previous crop is light and rainfall wet or medium. Examples of this occur in 1908, '11 and '21. A similar result is obtained by a combination of medium crops with dry summers as in 1912 and '22. Good blooms followed by poor or very poor crops occur after heavy crops with wet summers (1915), or heavy crops with medium summers (1920), or medium crops with wet summers (1913 and '23).

Table V.

Factors arranged in Descending Order of Cropping.

Previous Crop.	Previous Summer.	Expected Flower.	Expected Crop.
Light	Dry	Very good	Very good
Light	Medium	Very good	Good.
Medium	Dry	Very good	Good.
Light	Wet	Very good	Medium.
Medium	Medium	Medium	Medium.
Heavy	Dry	Medium	Medium.
Medium	Wet	Medium	Poor.
Heavy	Medium	Medium	Poor.
Heavy	Wet	Poor	Very poor.

The complete results are summarised in Table V. in descending order of flowering and cropping. In most cases a fair amount of flowers is developed. Bad flowering years are accounted for either by a heavy crop accompanied by a wet summer, or by any combination where the trees have suffered a severe aphis attack the previous year.

Woburn District.

The data applying to this place are found in Table VI. Column 3 contains the total crop weights in kilos on the selected plots, Column 4 the letter indicating heavy, medium or light crop, Column 5 the rainfall figures in inches for June-August, with indicative letter for wet, medium and dry summers, and Column 6, the crop estimated according to Table III.

The table is similar to Table II., except that no flower descriptions are available and a special column has been made for the average expected crop. This is necessary since the trees were young when crop records were first taken. The trees gradually have a larger bearing surface as the years go by and consequently may be expected to bear a continually larger crop.

In order to arrive at some sort of a figure on which to base an idea of the relative size of the crop an attempt was made to get an average figure for each

TABLE VI.

Relation of previous Apple Crops and Summer Rainfall to Crops of next year.

Woburn.

Year	Expected Crop Average. Kilos.	Actual Crop. Kilos.	Relative Description		Rainfall Previous June-Aug.	Estimated Crop.
			Current Year.	Previous Year.		
1899	364	173	L			
1900	728	2,039	H	L	D (3.40)	Very good.
1901	1,092	3,176	H	H	M (7.85)	Poor.
1902	1,456	1,181	M	H	D (5.58)	Medium.
1903	1,820	o F	O	M	M (7.60)	Medium.
1904	2,184	8,868	H	O	W (12.14)	Good.
1905	2,548	132 F	L	H	D (5.41)	Medium.
1906	2,912	5,352	H	L	M (7.50)	Good.
1907	3,276	7,403	H	H	D (5.32)	Medium.
1908	3,640	3,244	M	H	D (5.88)	Medium.
1909	4,004	13,386	H	M	D (4.99)	Good.
1910	4,368	3,299	M	H	W (9.40)	Very poor—poor
1911	4,732	14,733	H	M	D (5.69)	Good.
1912	5,096	1,903 F	L	H	D (3.64)	Medium.
1913	5,460	11,723	H	L	W (10.35)	Medium—good.
1914	5,824	498 F	L	H	D (2.85)	Medium.
1915	6,188	22,795	H	L	D (5.11)	Very good.
1916	6,552	757	L	H	M (7.54)	Poor.
1917	6,916	20,735	H	L	M (6.72)	Good.
1918	7,280	1,362	L	H	W (11.18)	Very poor.
1919	7,644	15,876	H	L	D (5.53)	Very good.
1920	8,008	609	L	H	M (6.65)	Poor.

Rainfall. Figures in brackets—inches. D—dry; M—medium; W—wet years.
Crop Description. O—none; L—light; M—medium; H—heavy.
F—frost in Spring.

year. To do this an average of the first four years' crop and the last four years' were taken as the two extremes. It was further assumed that between these points the trees would gradually and evenly increase in bearing powers. This, assumption is of course not strictly true, since in the early years a tree is slow in coming into bearing and in the later years quick to do so.

It is, however, the nearest approximation that can be made for purposes of comparison with the actual crop in order to decide whether the crop is relatively

heavy, medium or light. Partly as a result of this error the estimations for crops do not agree so well with the actual as in the case of Long Ashton estimates. It should be further noticed that the crop weights are collected in this case from a heterogeneous collection of varieties and forms, as well as from trees under differential treatment. Disagreements occur in 1901, 03, 05, 07, 10, 12, 14. These exceptions may be divided into two classes, those in which the crop is deficient, as in the years 1903, 05, 12, 14, and those in which the crops is in excess as in the years 1901, 07 and 10. All the first cases are accounted for by frost. Thus the screen minima on May 13th and 25th, 1903, were 32.4 and 30.7. Grass minima show on the average five degrees more frost, making this 7° of frost on the latter date. The year 1905 showed six frosts in May, the lowest being 24.6° screen reading. In 1912 on May 1st a temperature of 29.5° in the screen was recorded, and in 1914 six frost screen readings, the lowest being 25°, were also recorded. There is good evidence therefore to show that for these four years frost was the deciding factor. Four years in twenty-one years record is certainly an undue number and suggest that the Woburn Station was not suitably situated for growing fruit. In a similar series of years for the Long Ashton district no clear case of frost damage has been found.

The second cases, where the crop is in excess of the estimates, can be less easily accounted for. It should be remembered, however, that two factors introducing uncertainty are present, the differential treatment given experimentally and the impossibility of obtaining a true figure for the expected crop. It is known of course, that high manuring will under certain circumstances add to the food reserves available for the spurs and thus aid cropping the next year. The irregularity in 1901 may perhaps best be accounted for by the fact that the trees were only just coming into bearing. The excess in 1907 is largely due to the extra large crop borne by the Bramley dwarfs and standards, plots 1-11, 22-41, 189-200. In 1910, while most groups gave a considerably lower crop than in 1919, a few gave equal crops this making the total higher than it should be. The system if applied to the individual group works correctly, but if applied to a mass of uneven trees causes errors. At Long Ashton, where the crop amounts were obtained from large areas no such discrepancies occurred. For the other years the estimated and actual crop agrees reasonably well and thus supports the evidence obtained from the Long Ashton conditions.

Conclusion.

The evidence cited appears to show that, when stock influence, manuring and pruning are eliminated, the two factors of the previous crop and previous summer rainfall, by their interaction, are largely influential in deciding the amount of the future crop.

Also that these two factors, in trees not interfered with by pests or disease, by their interaction determine the amount of flower produced, but that the amount of flower produced is not a certain indicator of the following crop.

That when a bad aphis attack was present the crop for the following year was reduced far below the expected amount.

That the action of frost in spring caused a similar drop, but that the importance of this factor has probably been overrated.

That from a consideration of the results it should be possible firstly to forecast the probable crop over the country and secondly for the individual fruit grower to forecast his own particular crop. To do this he must also allow for any manurial or pruning treatment he is himself giving. As pointed out previously in this paper, it is quite possible to throw trees into continuous cropping by regulating the manurial factor and "water factor" in the right direction. Frequently it is simply a case of right manuring both quantitively and qualitively but in many cases occur in the field where this does not avail. In these cases the grower must rely on altering the "water factor," which can be done by temporarily withholding manure and by applying the proper pruning, as well as by ringing and cover cropping. It should be clearly recognised, however, that though such treatment may move the condition of the tree in the desired direction, namely cropping, it may not keep it there.

Every year the condition of the tree musts be judged and the treatment given it must be based on the results of that judgment. Fruit growing is, in fact, an art based on science.

SUMMARY.

1. This paper sets out the evidence showing the influence of the previous summer's rainfall (June-August) and the previous crop on the current year's cropping in apples.

2. The normal phase of growth in a one-year-old apple shoot is described, and its connection with cropping of the future tree discussed.

3. Current opinions of the factors influencing cropping may be grouped under three heads, Flower Production, Spring Weather and the Previous Crop.

4. It is maintained that far greater attention should be paid to the internal condition of the tree than to external conditions at the time of setting ; that this internal condition depends on the presence and position of organic food reserves ; that their presence depends, after eliminating pests and diseases, on proper manuring, but that the amount depends on (*a*) the weight of the previous crop, and (*b*) on the date at which extension shoot growth ceases ; this latter again depends to a small extent on the amount of crop borne, but to a far larger extent on the rainfall during June, July and August.

5. When the influence of pests, diseases, manuring, pruning, and stock influence are eliminated, therefore, the remaining factors of previous crop and summer rainfall determine the future crop in the large majority of cases.

6. Data illustrating rainfall figures and cropping for Long Ashton district and for Woburn are presented together with crop estimates based on a key table.

7. The connection between the previous year's rainfall and crops on the resulting development of flower and crops for the succeeding year is shown.

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ON "BURR-KNOTS" OF FRUIT TREES.

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It is common knowledge among fruit-growers and nurserymen that certain varieties of apples produce what are known in this country as "Burr-knots," or "Root-knots." These are tumour-like swellings which sooner or later produce a crowded mass of wart-like projections suggesting incipient roots. They are found on the main stem and on the branches, often at the junction of a branch with the stem, and at the nodes where the younger branches come off from the older ones. Generally they are at nodes; in many cases they arise at places where, although there is no branch or spur, dormant buds would be situated. They are common on certain varieties of apple and quince, and have been observed by us on several seedling plums as well as on certain plum varieties employed as root-stocks (Plate I.).

Many of the apple stocks (including both "Crab" and "Paradise" types) which are raised at East Malling and elsewhere, produce these outgrowths in varying degrees when allowed to grow into trees, and in the "Museum" plot on the Station a number of such trees bear typical examples of these burr-knots. Further, a number of these varieties of "Paradise" Apple Stocks in common commercial circulation (of which the Malling types are mainly selections) show these knots pronouncedly at two years old, prior to "working."

Two distinct forms of knot can be recognised. One form arises as small rounded swellings on the three or four year old wood; these increase in size retaining their smooth round contour until they reach a diameter of about two inches, when they become more irregular by the development of warty projections. This form is well seen in our Type IV. (Figs. 4 and 5.).

In the other form the knot is very irregular from the first and the wart-like projections are evident almost as soon as the knot arises; in the young knot the warts, or incipient roots, are few, but they increase in number with the size and age of the knot. This kind of burr is admirably shown by Crab J (Plate II Fig. 7.) but it is also seen on Type I. (Broadleaf), Type II. (Doucin), and Type V. (Doucin Amélioré).

Intermediate forms appear on other varieties where the young knot is more or less rounded at first, but loses its smooth outline before reaching any considerable size.

Besides forms there are differences in the period in the tree's life in which the knots become apparent. On some stocks such as Type III. they even

sometimes appear the first year, whilst on others such as Type II. knots appear only after a few years.

The knots may appear at a considerable distance above the ground. On some fifteen year old trees at East Malling they are to be found from just above ground level to four or six feet above the ground. It is sometimes stated that burr-knots reduce the vigour of the trees bearing them. The trees growing at East Malling offer no support of this statement, as trees (now fifteen years old) bearing numerous large knots still produce vigorous growth each year.

This manifestation of aerial root-knots is by English horticulturists very commonly associated with a ready rooting habit from layers or cuttings. In actual fact, observation has shown that there is a very close correlation between knotting and ease of rooting, though there are exceptions, usually in the negative direction, i.e., that certain free rooting varieties do not show burrs in quantity, at least in the early years. On the other hand, prolific knotting is a sure sign of easy rooting.

There is considerable evidence to show that at least from the seventeenth century these facts were well known and from that time onwards it is hardly an exaggeration to say that presence of root-knots formed one of the principal bases of stock selection in Europe, for what were called the " Paradise " varieties.

One of the earliest references appears to be in Francis Drope's " A Short and Sure Guid in the Practice of Raising and Ordering of Fruit-Trees " (1672). Talking of Apple Stocks not raised from seed he says, " The best sort of these are such whose bark is smooth and green . . . and the knots thin set on them. These marks shew, that they are either descended from seed, or at the least plants of themselves, and not dependent on the old maimed trunk."* He continues that if they are " full of knots " they are very difficult to graft, " and if notwithstanding this they thrive, the young sprigs through an irregular nourishing of the whole, are more subject to the canker." He goes on to say that the business of multiplying stocks by layers is " not yet vulgarly known," and having detailed many methods of bending down branches, etc., he gives a method for producing roots on branches that will not bend down " by slicing off small pieces of the bark and hacking it a little in the place where the roots should issue forth, and then placing an old boot over the bough, so that the middle of it be the conteiner of the place that is sliced . . . and filled with good earth . . . but it often happens that instead of roots there is only certain extuberancyes, or knots arisen in several places about the slicings, which are but so many preparatives for roots against the ensuing year." He also mentions in this connection varieties of apple Kentish Codlin, Nurse-Garden and Sweeting known and quoted by other writers as showing burr-knots.

* *loc. cit.* 98-99.

About the same period another writer, whose reference we have unfortunately lost, gives instructions for providing stocks for dwarf Apples. "In October from such trees, whose cuttings will grow, take such stems . . . which are an inch or more thick . . . cut them off if you can, an hands breadth below such knots or burs as are on them (for at those Burs they principally put forth their roots) . . . You need not fear setting these as deep as the length will bear, . . . because they will shoot out roots all along, almost to the top of the ground." Again, telling how to raise stocks by "circum-position" to bring these knots or burs upon branches "fasten about them some earth in an old hat, etc."

The writer finally recommends this method being used only on such varieties are as "apt to put forth roots" such as "the Kentish Codling, the Gennet Moil, some sorts of Sweet Apples, and Bitter Sweets,—and the Paradise Apple tree, which is much recommended by Mr. Rhea, for to raise Stocks for Dwarf Apple trees."

From this time onwards English horticultural literature faithfully hands on and enlarges upon this theme, whilst horticultural practice acted upon it as a matter of course. This point of view appears to have been overlooked by most American workers on the aerial galls of fruit trees, but in our opinion it cannot be ignored.

It may be interesting to add that in many country districts to-day local apples are handed round from garden to garden by means of root-knotted branches. Norfolk is a typical example and Mr. Goude, the Horticultural Superintendent for that County, informs us that certain local varieties, e.g., Happisburgh and Norfolk Codling are handed on from garden to garden by means of cuttings bearing burr-knots.

We could quote similar cases from all over the country, and we now have a fairly extensive collection of such varieties. Whilst most of these are only of local origin and notoriety, not a few are well-known and still are, or have been at one time or another, widely circulated commercial varieties, such as Oslin, Kentish Codling, Manx Codling, and Warner's King. The "Codling" family of apples especially have always been traditionally associated with burr-knots and have been widely used as root-stocks on that account.

One old English apple is actually named "Burr-knot," or Bide's Walking Stick, the story of the rooting of which is told by Hogg in his "Fruit Manual."

Finally, it is fairly clear, from both horticultural literature and practice, that this knotting habit was associated with moderate sized, even dwarfed, and quick cropping trees, and that the characteristic became associated with the so-called Paradise Stocks. This characteristic of many Paradise Stocks was described, illustrated and emphasised in our First Report on Paradise Apple Stocks (5). In our later report (6), we showed that most beds of Seedling

"Crabs" and "Free" Stocks contained many root-knotted plants, and in one case we actually recorded fifty per cent. of the seedlings as having "many" or a "medium number" of knots.

In this connection it is interesting to reflect that many of these collections of "Free" Stocks (raised from Pomace) are but the chance seedlings of those very Sweets and Bitter Sweets recommended by our ancestors as "knot apples."

On the other hand, there is a type of "Crab" (of which, however, there appear to be many varieties, yet all small leaved, scrubby, thorny, and "hard" wooded, bearing quite small fruits and generally found away from cultivated apples in such places as the New Forest and Sutton Park, Stafford) that approximates more to the description of true Crabs (*Pyrus Malus* L.) than do the majority of Commercial "Free" Stocks; this type is represented in our Collections by Crab H. It is noteworthy that representatives of this group rarely, if ever, exhibit Burr-knots and are generally difficult to reproduce vegetatively.

As shown from the above evidence it has been general experience that the presence of these knots is an indication that the tree bearing them can usually be readily propagated by cuttings, the incipient roots on the knots growing out as tufts of adventitious roots, and twigs and branches are frequently used for this purpose of propagation. The knots therefore, are generally regarded in this country merely as characteristic features of certain free-rooting varieties and we have found that the readiness with which roots develop from the knots can be easily demonstrated (see below). On one tree (Seedling E Crab) which produces large burr-knots, the lower branches assume a drooping habit and where the knots on these branches touch the soil roots grow out. Several other stocks also frequently "lay" and root their lower branches from such knots.

These outgrowths are well-known on the Continent particularly in Germany where they are referred to as "Kropfmasern." Under this name Kissa (10) in 1900 described them as occurring on *Pirus malus chinensis*, and in 1918 Jaeger (8) mentions them for apple. Lüstner (11) found that Kropfmasern on apple branches produce strong fleshy roots when placed in a moist warm atmosphere. He, however, regards the knots as pathological and recommends that cuttings for propagation should not be taken from "diseased" trees. A general account of these Kropfmasern as occurring on various forest and fruit trees is to be found in Sorauer's "Handbuch der Pflanzenkrankheiten" (13).

Wolf (16) found, on fig twigs in Alabama "numerous cylindrical or conical outgrowths" which he considers to be similar to the Kropfmasern of Continental writers; when he placed such twigs in moist soil "all of the outgrowths which were buried in the soil continued to grow so that within ten days many of them were an inch or more in length."

The intensive study that has been made in America of the tumours known as Crown-gall (caused by *Bacterium tumefaciens*) and of a pathological condition known as Hairy-root, which has been found to be associated with the presence of the Crown-gall organism in the tissues from which the abnormal roots arise, has led to the idea that the stem tumours (or burr-knots) are a form of Hairy-root. This view, however, has not been universally accepted and American workers are not unanimous as to the nature of these knots. Two well-known American horticulturists visiting this country on being shown burr-knots on the trees at East Malling expressed opposite opinions; one declared them to be an aerial form of Crown-gall, the other said they were not a form of Crown-gall.

Hedgcock (7) in 1908 described and illustrated stem tumours on apple and quince trees. From his illustrations there is no doubt that the tumours he described were similar to those we have examined. Hedgcock found that when "diseased" branches were cut off and left covered with moist soil for about four weeks "a number of the tumours had produced roots in abundance from the surface, but no roots were thrown out from any other portion of the limbs." He also stated that the knots agreed in appearance and structure with a form of Hairy-root and therefore concluded that they were an aerial form of Crown-gall. Clinton (3) in 1920 accepted this explanation.

In American literature we can find no reference to burr-knots on fruit trees as denoting easy propagation except in a recent paper by C. F. Swingle (14) who himself writes, "Except for the bare mention of their occurrence on willow, the writer has been unable to find a single sentence in American literature regarding non-pathological, dormant, stem-borne roots in any plant." Swingle records the occurrence of burr-knots on a large number of American varieties of apples and he has also found (15) that cuttings bearing root rudiments (burr-knots) readily rooted.

Recently, these stem tumours have been investigated by Miss Nellie A. Brown (at the United States Bureau of Plant Industry) who has had considerable experience in isolating the Crown-gall organism from true Crown-galls and Hairy-root material of apple trees. She states (1) that although several hundred plates were prepared from the stem knots the Crown-gall organism was never obtained from them and she is of the opinion therefore, that the stem tumours are not Crown-gall.

Our own experiments bear out Hedgcock's results in so far as we find that the stem knots produce roots freely when branches bearing them are planted up, but they also confirm the conclusions of Brown in the fact that the stem tumours we have examined have never yielded an organism related to *Bacterium tumefaciens*. Repeated attempts to obtain an organism from such knots by taking particles of tissue from the interior of the tumours (avoiding outside contamination), and placing them in culture media, gave almost invariably no

growth whatever and when occasionally growth did appear it bore no resemblance to that characteristic of the organism obtained from true crown-galls by similar technique.

Our experiments to test the ready rooting of branches bearing stem tumours were carried out in February, 1925, by merely cutting off branches (from 1 foot to 2 ft. 6 in. in length) bearing knots, and planting them up so that the knots were covered with soil. Some were planted in pots and placed in a cool greenhouse ; they were occasionally watered but received no special treatment. Others were planted out in the open ground and afterwards given no further attention until they were examined in the autumn. The pieces were cut and planted on February 27th, i.e., before the buds had begun to open. Some were photographed before planting up and are shown in Plate II.

On April 24th, those in pots were turned out and examined, with the results here tabulated.

Tree*	No. of cuttings taken.	No. alive on Apr. 24.	Remarks.
Crab B	5	5	Good growth of leafy shoots from the buds above ground : good root development from the knots : roots to 4 inches in length.
Crab E	2	2	Leafy shoots developing ; roots growing out from the knots but growth not so good as in B.
Crab G	3	2	One showed no growth and was apparently dead ; the other two had produced roots from the knots ; growth not so good as in B.
Crab J	5	5	Good growth of leafy shoots from the buds ; the knots had produced numerous roots up to 4 inches in length.
Paradise (Malling Type IV.)	4	1	One had grown out well but it was not so forward as in the other types ; the knot had produced stout roots up to 4 inches in length. The other three showed no growth.

* The trees are indicated by the letters on numbers which are used to distinguish them in the Museum plot.

Those planted out in the open were examined on May 28th, to see whether any development had taken place from the buds ; the underground parts were not examined until October 29th, when roots were found to have developed from the knots on all the trees which showed growth above ground.

It will be observed that the knots which develop aerial incipient roots early are those which root most readily when planted up. Thus of nine cuttings taken from Crab J, and ten from Crab B (both of which have knots which produce

Tree.	No. of cuttings taken.	No. alive on Oct. 29.	Remarks.
Crab B	5	5	All alive and healthy looking.
Crab E	3	2	Two alive and healthy; one of these bore flowers.
Crab G	7	7	Five only showed growth on May 28, but all had grown out by Oct. 29.
Crab J	4	4	All alive and vigorous.
Paradise Malling Type IV.	7	3 (+2 with a few roots).	Two alive and growing well. One alive but with weak shoots. Two showed no growth above ground but a few roots had made a little growth. Two quite dead, no roots had grown out from these.

incipient roots almost from the first) all produced well-rooted trees; on the other hand, of eleven cuttings taken from Type IV. (a type that produces rounded knots from which incipient roots arise comparatively late in their development) only three made well-rooted trees, five made no growth whatever, and two produced a few roots only. Trees of Crab E and G produce knots of an intermediate form and the cuttings from these "strike" better than those of Type IV., but not so well as those of Types B and J.

As already remarked some of our Paradise (layered) stocks are characterised by their free-rooting, the roots growing out from the nodes of the layers in tufts resembling somewhat the bunches of roots growing from the burr-knots. This condition again, in our opinion, has no connection with Crown-gall or Hairy-root, but is merely an expression of the free-rooting propensities of these stocks. Only one example of what we believe is true Hairy-root has come to our notice at East Malling. One stock was found producing at one node a bunch of fine silky-hair-like roots, the other roots on the same stock being of the usual type; in this case an organism was isolated from the swollen base from which the hair-like roots arose, and this organism in culture is similar to the organism which has been isolated from true crown-galls sometimes found on our stocks. It seems certain then that the type of rooting characteristic of certain Paradise stocks is not pathological and the rejection of such stocks merely because they show bunched roots is, in our opinion, an arbitrary procedure which is unwarranted and may cause the loss of valuable nursery stocks.

This free rooting of some of our stocks was so unfamiliar in America that when we sent out our first consignment of apple stocks (at their request) they were destroyed at the port of entry on the ground that they showed hairy-root!

In America the Seedling Apple Stocks are examined for signs of "hairy-root" at the time of transplanting and all suspects are rejected. A visit in 1923 to the

United States made it possible through the kindness of the United States Department of Agriculture for one of us to examine a considerable batch of these rejected stocks. In this country the vast majotity of these—from the cultural point of view—would never have been rejected for hairy-root, but would have been considered typical representatives of our free-rooting types of stock.

It is necessary, therefore, to distinguish between Burr-knots and free-rooting on the one hand and Crown-gall and Hairy-root on the other. The former are not in our opinion, of a pathological nature and contain no parasite ; the latter are caused by a parasitic bacterium and must be looked on with suspicion although the balance of evidence is now going in the direction of showing that Crown-gall causes little or no damage to fruit trees after they are planted up in their permanent quarters (12, 17).

The term " Root-knot " is sometimes used for Crown-gall, particularly in New Zealand, where it has been used in this sense by Campbell (2), Kirk (9), and Cunningham (4). As the non-parasitic aerial outgrowths have been known for centuries as " knots," and since Crown-gall is now known to be of a different nature, confusion is likely to arise by referring to Crown-gall as Root-knot. This, should be reserved for use in the sense employed in this paper.

Summary.

1.—An account is given of the value set by horticulturists on " Burr-knots " or " Root-knots," in relation to the propagation of those varieties of fruit trees which produce such knots.

2.—Branches or twigs bearing Burr-knots, when used as cuttings with the knots covered with soil, produce roots readily from the knots.

3.—Attempts to isolate a pathogenic organism from Burr-knots of fruit trees have given negative results.

4.—The writers' observations confirm recent work done in America and offer further evidence that Burr-knots have no connection with Crown-gall or Hairy-root.

Description of Illustrations.

1.—A " Crab " stock showing " Burr-knots " on the stem.

2.—Burr-knots on Quince.

3.—Root rudiments on Plum stem.

4.—Burr-knots on Apple Stock Type IV., showing incipient roots on the older knots only.

5.—Young knots on Apple Stock Type IV., showing their smooth contour.

PLATE I.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

6.—Similar knots to those in Fig. 4, bearing roots eight weeks after being planted up.

7.—Burr-knots on Apple Stock Type J, showing incipient roots even on the very young knots.

8.—The branch shown in Fig. 7, but eight weeks after being planted up; the knots have produced roots and the buds above ground have developed into healthy shoots.

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Note.—While this article was in the press two other papers, in which the Burr-knot problem is discussed, were brought to our notice, viz.:

Maney, T. J. The Propagation of Own Rooted Apple Stocks. *Proc. Amer. Soc. Hort. Sci.*, 1925, pp. 211-217.

Swingle, C. F. The Use of Burr-knots in the Vegetative Propagation of Apple Varieties. *Ibid*, pp. 228-230.

AN EXPERIMENT ON THE WINTER-KILLING OF VEGETABLE CROPS IN MARKET GARDENS.

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The experiment described in this paper was carried out as the result of an enquiry submitted to the writer by the Bristol and District Association of Market Gardeners on the occasion of a lecture given before that Association in November, 1923.

On that occasion the statement was made by several growers that they were no longer able to produce satisfactory winter crops in their gardens owing to the fact that the plants were killed during the periods of cold weather which occurred during the winter months.

The writer undertook to investigate the problem and the necessary facilities were placed at his disposal by members of the association.

A preliminary examination showed that the problem bore little relation to the original soil types of the gardens as plants appeared to be equally affected on soils as widely different as those derived from the light Pennant sandstones and the tenacious Lower Lias clays. In all cases where winter-killing occurred the land had been under continuous market garden cropping for a number of years—from ten years and upwards—and the information was obtained that plants were never affected on new land.

Plants growing on these old garden soils during the winter months invariably showed exceedingly poor root development and there was always a lack of fine fibrous rootlets. They could generally be pulled out of the ground without appearing to offer any resistance, thus showing that the roots had a very poor hold in the soil.

In broad-leaved plants such as cabbages and lettuces the marginal portions of the leaves always exhibited a scorched appearance, whilst the foliage of onion plants showed symptoms of dying back from the tips.

Similar symptoms were observed on cabbage plants and lettuce plants in some of the gardens during a dry period of summer weather.

The regular practice in the gardens is to grow such crops as celery, marrows and various brassicæ during the summer months, and to follow these with winter onions, winter lettuces and spring cabbages, etc., for the winter months.

The system of manuring followed is to apply very heavy dressings of town stable manure to the summer crops—from forty loads per acre upwards—as it is the opinion of the growers that without such heavy dressings of stable manure satisfactory results cannot be obtained with celery and marrows.

Of late years much trouble has been experienced from fungus diseases on the celery crop in many gardens, and hence it has become increasingly important that a successful winter crop should be obtained. In come cases the position has become so acute that the growers are contemplating giving up their old grounds and moving further into the country.

Description of Experiment.

A typical piece of land for the purpose of carrying out experiments was kindly offered by Mr. W. T. P. Hasell, at St. George, Bristol. The ground had been under market garden crops for forty years. Previous to being taken over for market garden purposes the soil was a very tenacious Lias clay soil which could only be dug over with a fork with great difficulty.

During the whole of the period that the land has been under market garden crops the practice has been to apply extremely heavy dressings of town stable manure and frequent dressings of lime and as a result of this treatment the soil has lost its original clay properties and now works like a light soil and is inclined to be " puffy." Indeed, the physical properties of the soil now appear to be determined almost completely by the high content of organic matter.

The garden was visited on December 5th, 1923, to examine the condition of plants in the winter state and to select a piece of land for experimental purposes. On this occasion, on certain plots in the garden, spring cabbage plants and winter lettuces were exhibiting the typical symptoms to a marked extent, showing marginal scorching of the leaves and deficient root development. The root systems of some of these cabbage plants were compared with some plants which had been raised in the same seedling bed and planted out on a new piece of ground, and it was noted that the latter plants had well developed fibrous roots and healthy foliage.

A border planted out with winter lettuces was selected as suitable for the purpose in view. The plants on the border were in very poor condition, a large proportion appearing to be practically dead and the grower was of opinion that another period of cold weather would kill most of the plants.

Two plots were marked out on the border for treatment. A composite sample of soil, to a depth of 9 inches, was taken from the border. The percentages of carbonate of lime and available potash and phosphoric acid were determined in the sample. It was proposed to carry out further determinations, but unfortunately the sample was mislaid in the laboratory.

The results obtained were as follows:

	%
Carbonate of Lime	5.85
*Available Potash (K_2O)	0.0410
*Available Phosphoric Acid (P_2O_5)	0.1838

* Denotes soluble in 1% Citric acid solution.

To one of the plots, which measured 40 yards by 5 yards, it was proposed to apply regular dressings of sulphate of potash to subsequent crops, whilst the remainder of the border was to be given no manure of any sort.

The reason for suggesting these treatments was that the writer, in his experiments on the nutrition of fruit trees, etc., (1, 2) has found that when plants are fed with nutrients in which the ratio $\frac{\text{nitrogen}}{\text{potassium}}$ is very wide the trees become affected with leaf scorch and the root systems formed are frequently deficient in fibre. In field experiments on gooseberries at this Station it has also been demonstrated that such feeding may actually prove so detrimental to growth as to actually reduce the condition of the plants below that of the plants on the unmanured plots.

It is generally held by growers that stable manure, being a natural manure, is a sufficiently well balanced manure, but in the writer's opinion, for horticultural purposes where large dressings are given regularly, this is not the case, such a practice leading to a condition of excess nitrogen in the plant food.

The programme of cropping and manuring arranged for the first season was as follows :—

The lettuce crop occupying the plot was to be followed by Seville beans as the 1924 summer crop, and the beans by winter onions for the 1924-25 winter crop. A dressing of sulphate of potash at the rate of 3 cwts. per acre was to be applied without delay to the lettuce plants on the " treated " plot and a similar dressing was to be applied to that plot at the time of the planting of the onions. The programme was carried out in its entirety.

RESULTS.

The effect of the potash dressing on the lettuce plants was not examined by the writer as it was thought that the plants were in too poor condition at the time of applying the dressing to derive any benefit from it. The grower however, was of opinion that the plants showed some response to the treatment.

Observations on the bean plants during the early stages of growth were carried out by the grower, who stated that differences in favour of the potash plot plants were evident from an early date.

The plots were inspected by the writer on June 26th at which time the stage of the first picking over had been reached. On that date it was quite evident that the condition of the plants on the potash plot was superior to that of those on the unmanured plot. On the latter plot the foliage was in poor condition, many leaflets were of an unhealthy green colour and exhibited pale marginal markings and blackened patches. The plants were also fairly badly affected with " Chocolate Spot " disease. On the potash plot the foliage was a much fresher green than on the unmanured plot, there being practically no

signs of the pale bands or the blackened patches on the leaflets. The plants did not appear to be suffering from "Chocolate Spot" to anything like the same extent as those on the untreated plot.

Owing to the difference in condition of the plants on the two plots the grower was obliged to clear the crop on the untreated plot before that on the potash plot.

As with the bean plants, the early observations on the onion crop were carried out by the grower and these observations again showed that from an early stage the plants on the potash plot made better growth than those on the unmanured plot.

The plants on the latter plot showed the typical deficient root systems, whilst on the former plot the root growth was normal in character. By December, plants on the untreated plot began to die off and it became necessary to commence clearing off some of the better plants on the plot to sell " bunched green " as it was obvious that the plants would otherwise be lost. The plants on the portion of the plot adjoining the potash plot were left untouched for comparison with the plants on the latter plot.

The plots were inspected by the writer on December 22nd. On the potash plot there was a normal " stand " of healthy plants. The root systems were well developed and the tops were about 12 inches in height. On the untreated plot the " stand " was very irregular, there being numerous bare patches where the plants had died out entirely. The best plants on this plot were also considerably behind the average plants on the potash plot. The difference in the development of the plants on the two plots was very marked.

Photographs of the plots, showing the condition of the plants, were taken on January 23rd, 1925. These are reproduced in Plates I. and II.

Discussion of Results.

In this experiment it was quite clear that both the bean crop and the winter onion crop responded markedly to the dressings of potash and that in the case of the latter crop the characteristic symptoms attending winter-killing were overcome by the treatment, as a normal " stand " of healthy plants with well developed root systems was obtained.

In view of these results the writer would suggest that winter-killing of crops in such soils is largely due to the wide ratio of $\frac{\text{nitrogen}}{\text{potassium}}$ in the plant food resulting from the practice of continuous manuring with heavy dressings of town stable manure and would recommend that growers experiment with systems of manuring using smaller dressings of town stable manure supplemented with dressings of potash manures instead of continuing with their present manurial practice.

PLATE I.

Showing the condition of the onion crop on the potash treated plot on January 23rd, 1925. Note the normal "stand" obtained and the vigorous condition of the plants.

PLATE II.

Showing the condition of the onion crop on the untreated portion of the border on January 23rd, 1925. The vacant strip along the edge of the border had been cleared. Note the thin "stand" and the poor condition of the plants.

Photographs by Mr. Wm. Camps.

SUMMARY.

1. The problem of the winter-killing of vegetable crops in market gardens in the district around Bristol is discussed in relation to the current manurial practice.

2. The results of a manurial experiment designed to throw some light on the cause of the phenomenon are presented.

3. A recommendation, based on the results obtained in the experiment, is made that growers should experiment with systems of manuring entailing the use of smaller dressings of town stable manure than at present, supplemented with dressings of potash manures instead of continuing in their present practice of relying wholly on large dressings of town stable manure.

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(1) *Wallace, T.* Pot Experiments on the Manuring of Fruit Trees. Annual Reports, University of Bristol Agr. and Hort. Research Stn., 1921, 1922, 1923.

(2) *Wallace, T.*, and *Hutchinson, H. P.* Note on the Root Systems Developed by Willow Cuttings in Nutrient Solutions. Annual Report, University of Bristol Agr. and Hort. Research Stn., 1924.

SOME FACTORS INFLUENCING THE PERIOD OF BLOSSOMING OF APPLES AND PLUMS.

By R. G. HATTON and N. H. GRUBB.

East Malling Research Station.

In 1919 a commencement was made in the recording of the blossoming season of some fifteen varieties of Commercial Apples in the Pruning Plot, and a similar number of Plums in the Variety Plot. These records were taken primarily for the information of those working at this Station, but since so many queries have been received from growers upon this subject, it has been decided to give a brief outline of the results.

Although the records are nearly complete for seven years, it must not be supposed that we ourselves regard them as an entirely reliable guide.

There are first of all the difficulties of the actual recording, many of which have already been referred to by workers on this subject. What for instance is to be regarded as " full bloom " ? This must depend very largely on personal judgment. We have, therefore, tried to reduce this source of error, as far as possible, by taking notes of the opening of the first flower, and the falling of the last, as well as trying to judge when fifty per cent. of the blossoms have opened. This last we have called " full bloom." But each of these records raises problems of its own. In even the most carefully selected group of trees of a single variety, some variation has always been observed; where these trees have been less carefully raised and selected the variation is certainly greater.

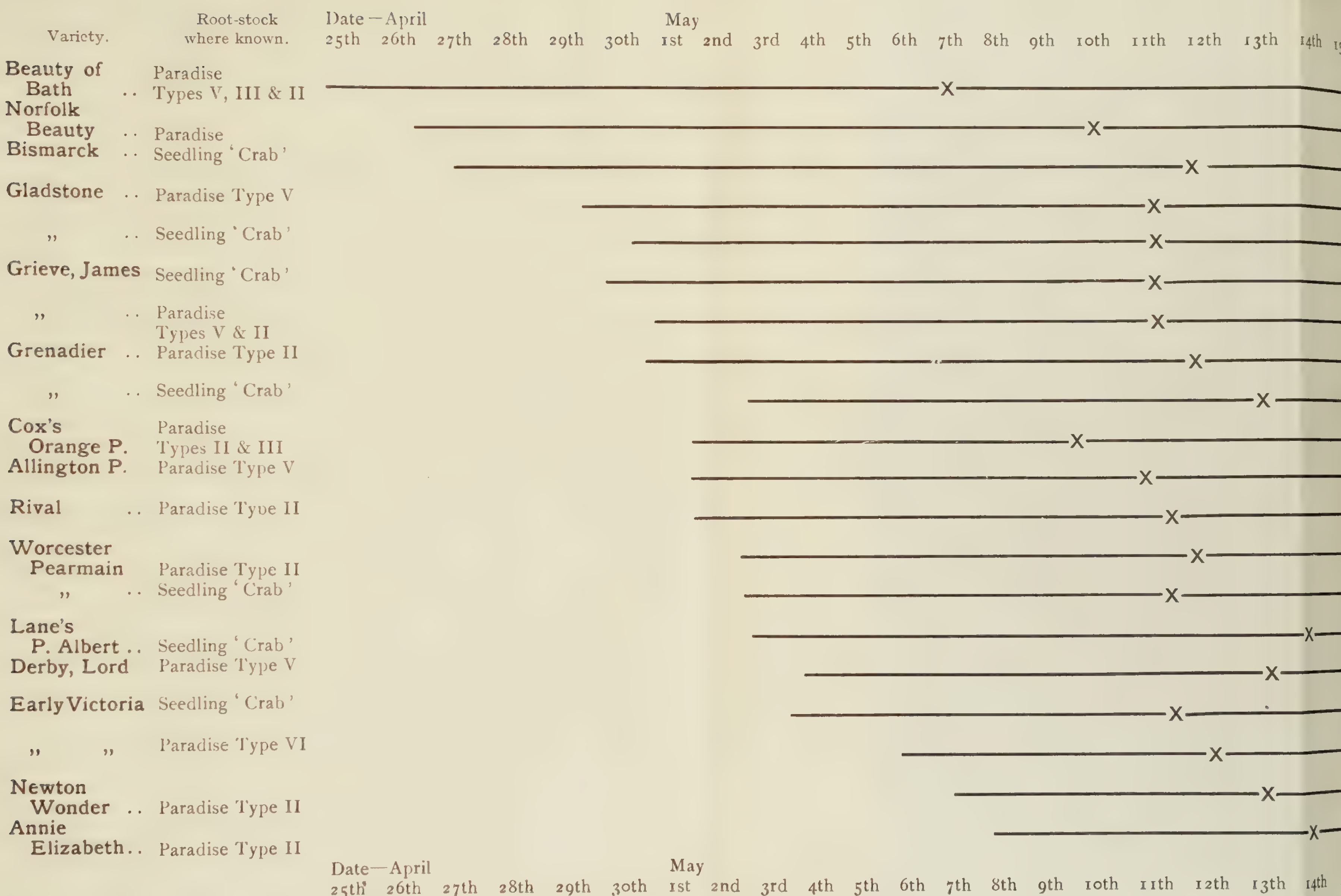
Such variations seem to be due to several causes, the most obvious of which will be those factors affecting amount of blossom. In any group of trees of bearing age, some are likely to be in their " off " year, and the resulting differences in the amount of blossom undoubtedly affect the length of the flowering period.

Again, proof has been obtained here—as will be shown later—of the effect both of different methods of Pruning, and the use of different Root-stocks, upon the blossoming period of any one variety. It is at least probable that other cultural factors, and insect attacks, may have similar effects.

In view of these variations, the records here have never been taken upon single trees. Groups of trees, from three to sixteen of any one variety, have been used for the observations, but, unfortunately, in most cases, it has been impossible to keep individual tree records. The difficulty, then, arises in recording as to whether the " average " is to be taken, or whether the first opening blossom on the earliest tree in the series and the last dropping blossom

TABLE I.

DIAGRAM SHOWING PERIOD OF BLOSSOMING OF APPLES ON



on the latest are preferable. In order to reduce the human factor this last course has been adopted and the average estimated only for the full blossoming. Even then a certain amount of personal judgment has to be exercised in disregarding "freaks" and peculiarities of certain trees. In this matter there may be a further element of error in our records owing to the fact that no less than six persons have during the period been concerned with these observations.

Whilst the writers made every endeavour to establish a uniform method of observation, the actual records in different seasons were also taken by Messrs. J. Amos, T. N. Hoblyn, H. M. Tydeman, and the Misses A. D. Mackenzie and K. P. Worsley, to whom best thanks are due for making this survey possible. On the other hand, the period of time over which the observations have been made, and their generally consistent character encourage the hope that the error is after all not so very great.

In the case of Apples, a diagram is presented showing the average period of blossoming on unpruned trees from 1919 to 1925. The pruning factor is thus eliminated. The trees were purchased from ordinary commercial sources, some, as has transpired from suckers, on true and some on mixed "Paradise," and others on variable Seedling "Crab" Stocks. The varieties of "Paradise" identified are generally those in most common use, Types II. (Doucin) and V. (Improved Doucin) predominating. As will be seen later, those trees which are worked upon Type II. may be slightly earlier in their blossoming period than those on Types III. ("Holly Leaf"), V., and VI. (Nonsuch). Despite these factors of variability, and that of the Seedling "Crab" Stocks, we get an "average" grouping of the varieties into early, mid-season and late, which is very generally borne out by a study of the year to year records.

It is satisfactory to find that this natural grouping and order very closely coincide with those recently published by Mr. Cecil Hooper, F.L.S., of the S.E.A. College, Wye, in the *Fruit, Flower and Vegetable Trades' Journal* of December 20th and 27th, 1924, and re-issued as *Fruit Bulletin* 10—S.E.A. College, Wye. Mr. Hooper's table is a compilation, not only of his own records at Wye, but of those from Wisley, Droitwich, Woburn and Long Aston, so that the evidence from all these sources would seem to confirm the value of at least a rough grouping of varieties into Early, Mid-season, and Late Blossoming.

Whilst it is clear that under East Malling conditions a lack of precise knowledge on the question of the relative blossoming season would not have led us into any grave disasters in planting together most of our varieties (since they so generally overlap), there is little doubt that between the earliest and latest groups cross pollenation might have been unsatisfactory. Seasonal vagaries actually increase this risk, as for example, in the year 1921, when Beauty of Bath was "full" on April 14th and Annie Elizabeth only started to open upon the

25th. However, fortunately for the Apple Grower most of the main Commercial varieties (including Bramley's Seedling, not yet included in our records) fall into a very close mid-season group, of which any two varieties may be regarded as generally likely to overlap.

The question of the suitable interpollenation of varieties of Apples is not here considered, since to the writer's knowledge no cases of intersterility in this fruit have so far been authenticated.

Table II. shows to what extent the relative order of flowering has been maintained from season to season in our conditions, and the dates of full flowering illustrate very well the wide differences in the actual time of blossoming of any individual variety owing to seasonal influences. These dates again show how seasonal conditions from year to year shorten or lengthen the relative blossoming period. For instance, whilst in 1921 twenty days elapsed between the full blossoming of Beauty of Bath and that of Lane's Prince Albert, in 1919, 1923, and 1924 the biggest differences were only four days.

It has already been mentioned that our records show a difference in blossoming period between pruned (tipped and spurred), and unpruned or merely " thinned " trees, of the same variety. This observation is mainly of importance to the research worker ; not only does it indicate the extreme caution necessary in selecting trees for such observations, but also it is suggestive that the reason of the difference appears to lie in the classes of fruit buds predominating on the treated and untreated trees. It seems to be the case here, that terminal fruit buds (on long shoots) are mostly early in their opening ; spur fruit buds (on short shoots) are mainly mid-season ; whilst axillary fruit buds are nearly always late. In the system of tipping and spurring here concerned, the terminal fruit buds are almost entirely removed, and axillary fruit buds largely so, and thus the blossoming season is apt to be " telescoped." There is some evidence to show that this effect of pruning varies not only from season to season, but also probably from variety to variety. The two varieties which blossomed most freely on the pruned trees in their early years, Newton Wonder and Beauty of Bath, show the effect less clearly than most of the remainder. It also seems probable that this effect is tending to disappear as the trees get older, the reason presumably being that the bulk of the fruit buds on all the trees are then on spurs.

However, even as late as 1923, the tenth year from planting, we recorded the unpruned trees of Lane's Prince Albert as starting into blossom nine days earlier than the pruned trees, and in that year on the average, all the varieties taken together showed that the unpruned trees started to blossom nearly four days earlier than the pruned trees. There have actually been cases where the unpruned trees have been as much as fifteen days in advance of their pruned neighbours of the same variety. From the point of view of " delayed dormant " spraying such a difference as this might even be of economic importance.

TABLE II.

Relative Order of Full Flowering of Apples from year to year. (Unpruned Trees.)

Variety.	Stock.	1919	1920	1921	1922	1923	1924	1925	Average Position
Beauty of Bath ..	P	1 *May 13th*	1 *Apl. 15th*	1 *Apl. 14th*	1 *May 17th*	1 *May 1st*	1 *May 15th*	1 *May 13th*	1
Norfolk Beauty	P	2 ,, *14th*	2 ,, *17th*	3 ,, *27th*	2 ,, *19th*	2 ,, *2nd*	1 ,, *15th*	2 ,, *14th*	2
Bismarck ..	S	12 ,, *16th*	9 ,, *22nd*	7 ,, *29th*	9 ,, *21st*	4 ,, *3rd*	4 ,, *16th*	5 ,, *16th*	7.1
Gladstone ..	P	5 ,, *15th*	— —	7 ,, *29th*	2 ,, *19th*	4 ,, *3rd*	11 ,, *17th*	2 ,, *14th*	6.2
Grieve, James ..	P	5 ,, *15th*	3 ,, *19th*	2 ,, *26th*	4 ,, *20th*	2 ,, *2nd*	4 ,, *16th*	5 ,, *16th*	3.7
Grenadier ..	P	2 ,, *14th*	3 ,, *19th*	7 ,, *29th*	4 ,, *20th*	4 ,, *3rd*	4 ,, *16th*	12 ,, *19th*	5.1
Cox's O.P. ..	P	5 ,, *15th*	6 ,, *21st*	6 ,, *28th*	4 ,, *20th*	4 ,, *3rd*	4 ,, *16th*	4 ,, *15th*	4.7
Allington P. ..	P	5 ,, *15th*	5 ,, *20th*	3 ,, *27th*	4 ,, *20th*	4 ,, *3rd*	4 ,, *16th*	8 ,, *17th*	4.7
Rival ..	P	5 ,, *15th*	6 ,, *21st*	3 ,, *27th*	9 ,, *21st*	4 ,, *3rd*	4 ,, *16th*	8 ,, *17th*	5.6
Worcester P. ..	P	5 ,, *15th*	9 ,, *22nd*	10 ,, *30th*	4 ,, *20th*	4 ,, *3rd*	4 ,, *16th*	5 ,, *16th*	5.9
Lane's P.A. ..	S	12 ,, *16th*	12 ,, *25th*	15 *May 4th*	9 ,, *21st*	13 ,, *5th*	13 ,, *19th*	12 ,, *19th*	12.3
Derby, Ld. ..	P	12 ,, *16th*	— —	10 *Apl. 30th*	9 ,, *21st*	13 ,, *5th*	13 ,, *19th*	12 ,, *19th*	11.5
Early Victoria ..	P	5 ,, *15th*	6 ,, *21st*	12 *May 1st*	9 ,, *21st*	4 ,, *3rd*	1 ,, *15th*	8 ,, *17th*	6.4
Newton Wonder	P	15 ,, *17th*	11 ,, *23rd*	13 ,, *3rd*	9 ,, *21st*	12 ,, *4th*	11 ,, *17th*	11 ,, *18th*	11.7
Annie Elizabeth	P	2 ,, *14th*	— —	13 ,, *3rd*	15 ,, *23rd*	13 ,, *5th*	13 ,, *19th*	12 ,, *19th*	11.3

P. Paradise. S. Seedling.

The influence of the root-stock upon the blossoming period of its scion has been definitely recorded for three seasons, now that all the trees have a considerable amount of blossom. These records have been taken upon five unpruned trees on each stock, and they seem to show that, at least in the early years, this factor is an influence to be reckoned with. Indeed on our plots of Lane's Prince Albert, where the trees on different root-stocks are intermixed, the difficulties of spraying the trees immediately before and after blossoming have been greatly increased by this factor of successional flowering.

Table III. shows diagramatically the variation in blossoming period of Lane's Prince Albert on different root-stocks. It will be seen that on the average of three years a single variety may vary from this cause to the extent of seven days in its first opening, and four days in full blossoming. In individual seasons the difference has been as great as ten days. Indeed, the difference has been so marked, and has persisted so late into the season, that growers unknowingly have remarked on the very different stages of development of the set fruit. The illustrations (Plates A & B) show typical trees of Lane's Prince Albert upon two different stocks in closely adjacent rows, photographed on the same day.

The effects of root-stock upon the period of blossoming are not confined to our soil and situation only ; identical data has been collected from our trial plots upon other soils. They do not appear to be in any way connected with the different times of blossoming of the different classes of fruit buds already mentioned in discussing the effects of pruning. If this were the case we should expect to find the relative order a very different one. As already mentioned, axillary fruit buds tend to be late, and yet trees on those stocks which show the strongest tendency to their formation happen to be amongst the earliest flowering, and *vice versa*.

At present no reasoned explanation of the phenomenon can be given, for although the more precocious and dwarfing root-stocks are mainly grouped at one end, and the most vigorous ones at the other, there are exceptions. Again, though it is true that Type VIII. comes into leaf itself very early, and Type XIII. rather late, yet contradictory evidence could be quoted. Indeed, we can cite a case of the early leafing and blossoming Malus baccata being fully " out " whilst the suckers from the root-stock upon which it is worked are still quite dormant ! The evidence in the case of plums is equally strong and contradictory. Plums worked upon the early leafing and flowering Myrobolan (P. Cerasifera) stock are amongst the latest to come into blossom if compared with the same varieties upon the late blossoming Pershore Stock !

This brings us to the consideration of our records on the blossoming of Plums, which are presented in diagramatic form in Table IV. Unfortunately the average blossoming period of the Cherry Plum (Myrobolan, P. Cerasifera), to which reference has just been made, cannot be included upon the diagram

Seven Year Old Lane's Prince Albert Apple on Rootstock, Type IX.
Showing Blossom Fully Open on May 14th.

Seven Year Old Lane's Prince Albert Apple on Rootstock, Type XIII. Showing Blossom still Unopened on May 14th.

PLATE C.

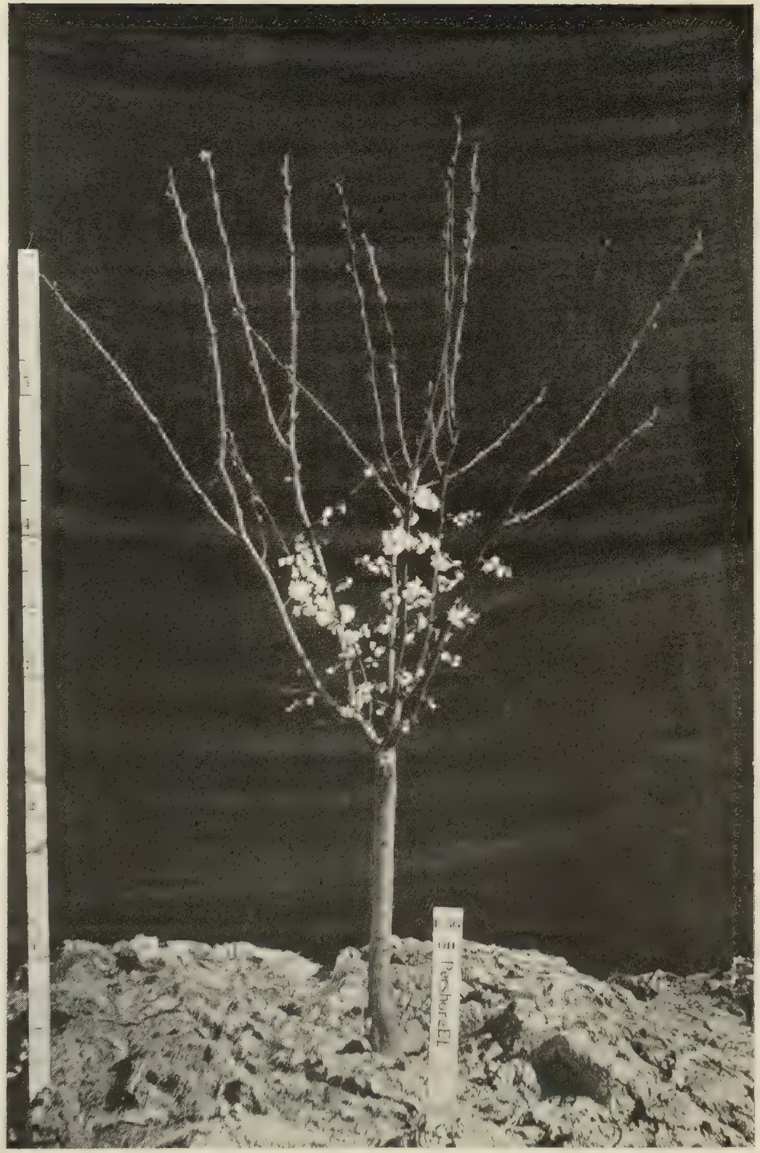
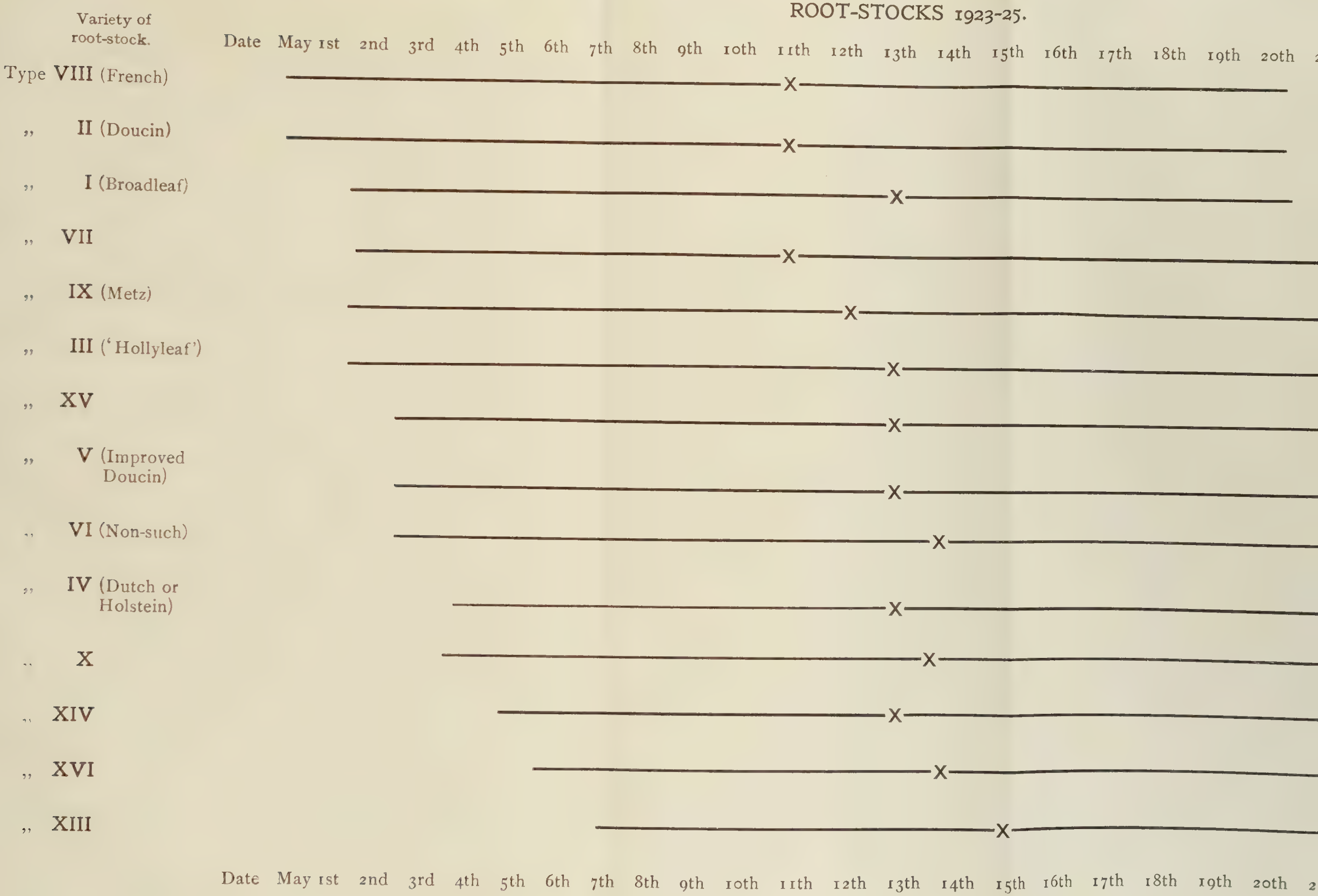


TABLE III.

DIAGRAM SHOWING VARIATIONS IN BLOSSOMING PERIOD OF LANE'S PRINCE ALBERT APPL
ROOT-STOCKS 1923-25.



TAB OSSOMING OF PLUMS—AVERAGE OF 5-7

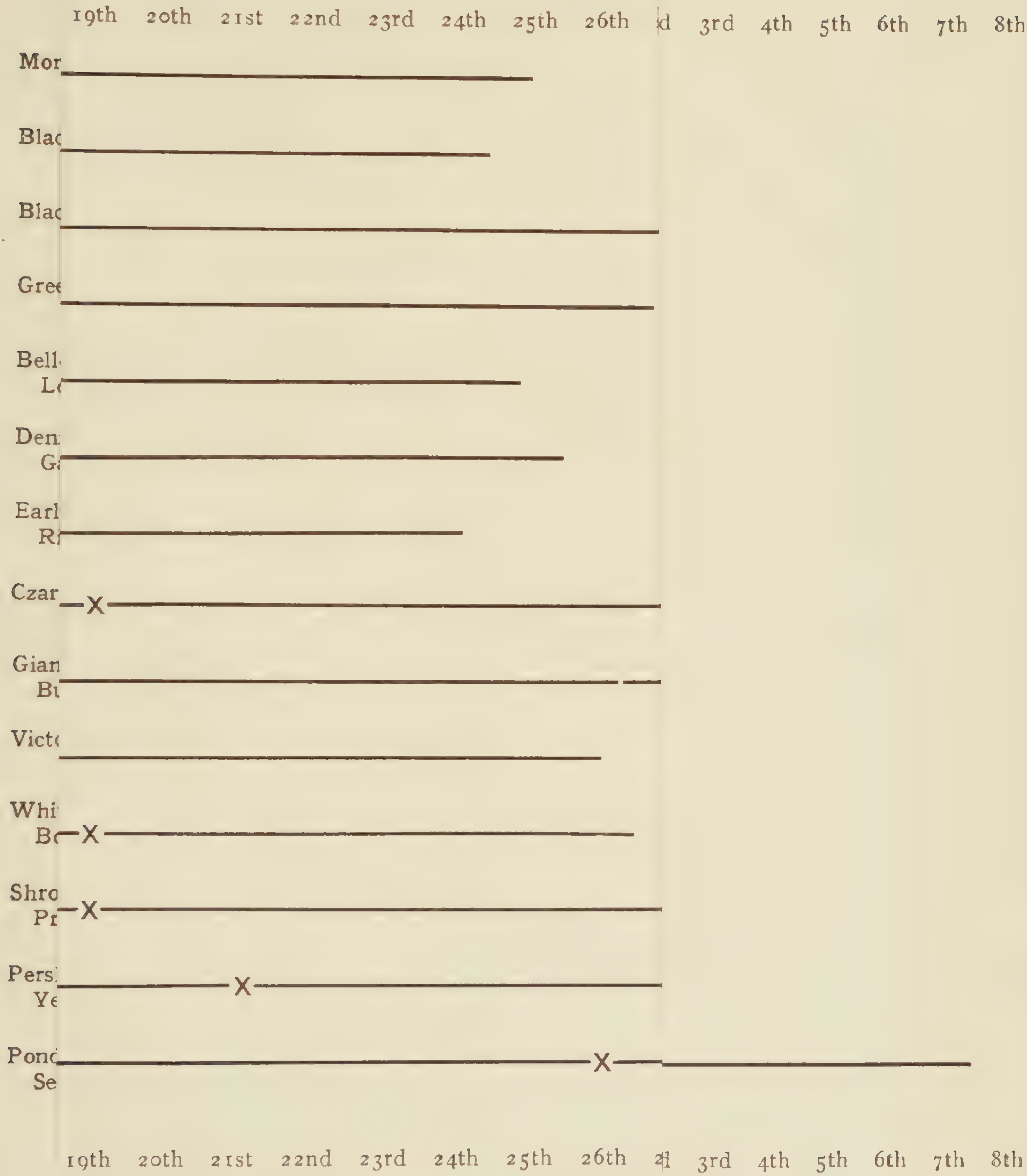
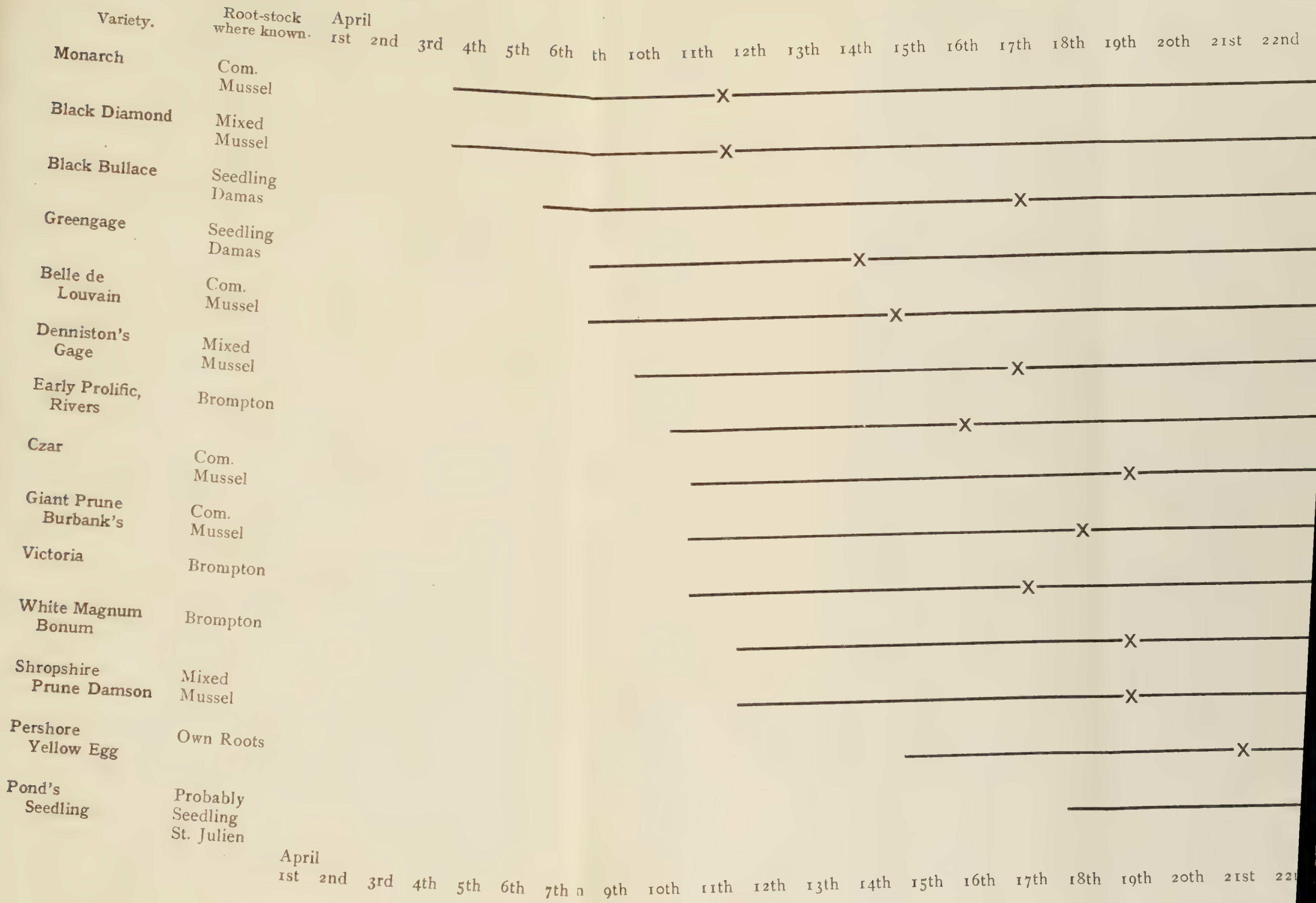


Table IV.

DIAGRAM SHOWING PERIOD OF BLOSSOMING OF PLUM



because it extends from March 2nd until April 3rd, and so does not overlap with any of the P. Domestica and P. Insititia varieties included in the table.

The records have been taken on groups of three trees of each variety. The trees were bought for a variety plot upon various root-stocks, most of which have since been identified from their suckers. The trees have only been lightly thinned occasionally.

As in the case of Apples, we have records to show that the root-stock to some extent affects the time of blossoming. Victorias, Czars and other varieties appear to come into blossom considerably earlier on Common Mussel and Pershore Stocks than they do on Brussel and Myrobolan roots. Intermediate between these two groups of stocks, the other varieties seem to range themselves.

Our two illustrations, (Plate C) showing typical adjacent trees of Victoria Plum upon different root-stocks, bear witness to stock effect on time of blossoming very well. Unfortunately the incidence of "Silver Leaf," "Die Back," etc., amongst our experimental plum trees has so thinned out their numbers and cut across our recording, that we cannot yet present the amount of data that we can in the case of Apples; however, the same effects have been noted on more than one soil. How far it may be possible to utilise advantageously this control of the earliness and lateness of blossoming depends upon the range of effect that can be established. It must be remembered that up to the present, in the main, only stocks in general commerce have been selected and tested, and that, as yet, no selections have been made from this particular point of view. Indeed, until we know the cause of the influence, we have no better basis of selection than chance, since the season of the stock itself is a misleading guide.

With regard to our actual order of blossoming, it is again encouraging to find that this agrees very generally with Mr. Cecil Hooper's compiled list, where we can feel confident that our varieties are the same. There are, however, two notable exceptions. Both Czar and Belle de Louvain come very much earlier in our list. It will be noted, however, that in our plot both these are worked on Common Mussel, which, as we have already said, makes for early flowering.

Our list can only be taken as a very general guide to the relative blossoming period, and we have made no experiments with regard to intersterility. For this aspect of the question, reference should be made to the publications of Mr. M. B. Crane, John Innes Horticultural Institution, Merton, Surrey, and Mr. A. H. Rawes, of the Royal Horticultural Society's Gardens, Wisley.

THE PRESERVING QUALITIES OF DIFFERENT VARIETIES OF FRUIT.

CANNING AND BOTTLING TRIALS:

I. RASPBERRIES AND GOOSEBERRIES.

By F. HIRST.

University of Bristol Research Station, Campden, Glos.

A CONSIDERABLE proportion of the fruit grown in this country is preserved in some form or other on a commercial scale. The different fruits are canned or bottled, or made into jam. Since individual varieties differ considerably in the quality of product which they yield, it is important to know which of the many varieties of any fruit are the best for preserving purposes. They are now being studied at Campden from this point of view.

In recent years the demand for canned raspberries has increased, and there is no reason why this increased demand should not be met by the canning of suitable varieties of home-grown fruit. Experiments carried out at Campden have shown that an excellent canned product can be obtained provided a heavy syrup is used as the covering liquid, and that the berries are packed in well lacquered cans.

The following is a preliminary Report on variety trials of raspberries and gooseberries in relation to canning and bottling.

1. RASPBERRIES: (CANNING).

In an endeavour to find the best varieties of raspberries for canning purposes, a number of varieties grown at the Long Ashton Research Station under uniform conditions were processed there by the author during the past fruit season.

In all cases the procedure was the same. The berries were hulled and roughly graded by hand, only the firm fruit being put into the cans. The latter were washed in hot water previous to being filled with fruit. They were packed to within one-eighth inch of the top, a weighed quantity of fruit being placed in each can. The cans were then filled up with hot syrup and sealed at once. The syrup was prepared by dissolving sugar in water, 6-lbs. of sugar being added to each gallon of water. All the cans were sterilised for fifteen minutes at 100° C. They were then immediately placed in cold running water, and left until cold.

When the products were examined, it was found that the fairly hard water at the Long Ashton Station had affected the colour of the canned fruit to a

certain extent. At the same time it was easy to distinguish which of the varieties tested were the best for canning purposes. From these preliminary experiments, the following varieties gave the best results:—Lloyd George, Calstock Seedling, Baumforth's No. 2, Semper Fidelis, Fastolf (Burnham), Blackshaw Station, Bourton Coombe, and Bunyard's Profusion. Fairly good results were obtained from Baumforth's No. 1, Devon, Worcester Prolific; and Pyne's Fillbasket.

Further work with these and other varieties will be carried out over a number of seasons to ascertain the nature and extent of seasonal influence.

The following notes summarise the results of the 1925 trials.

Variety.	Appearance before processing.	Colour of canned product.	Flavour of canned product.	Any other remarks.
Lloyd George	Berry conical in shape	Good	Good	Kept its shape well.
Calstock Seedling	Large round firm berry; good colour	Good	Good	Good shape and size.
Baumforth's No. 2	Firm berry of good colour	Good	Good	Berry firm and of good shape in can.
Semper Fidelis	Nice large firm fruit; rather dark in colour	Good	Good	Good shape and size.
Fastolf (Burnham)	Round berry; medium size	Good	Good	Very good product.
Blackshaw Station	Very soft; rather a dark variety	Good	Good	Had not kept shape very well.
Bourton Coombe	Good size	Good	Good	Good shape and size.
Profusion (Bunyard's)	Good sized fruit; rather oblong shape	Good	Good	
Baumforth's No. 1	Round Berry; good colour; rather soft	Fairly good	Good	Kept its shape well in processing.
Devon	Firm berry; rather dark in colour. Large and conical in shape	Fairly good	Good	Kept its shape very well indeed.
Worcester Prolific	Large juicy berry	Fairly good	Good	Was fairly soft; but had not become disintegrated.
Fillbasket (Pyne's)	Rather small berry	Fairly good	Good	Berries small but uniform.
Monarch (Fell)	Nice dry berry; good colour	Very pale and slightly brown	Fair	Good shape and firm.
Red Antwerp (Rivers')	Good colour; round juicy berry	Fair	Fair	Moderate result.
Fillbasket (Parsons')	Medium sized berry	Pale	Good	Berries faded.

Variety.	Appearance before processing.	Colour of canned product.	Flavour of canned product.	Any other remarks.
Prior's Prolific	Fruit firm ; not very juicy tends to be orange coloured.	Fair	Good	Firm berry of good size.
Reader's Perfection	Small berry ; very soft and rather dark in colour	Syrup red ; berries brown	Poor	Good shape.
Improved Beehive	Small round berry ; good colour	Very pale	Poor	Had kept its shape.
Northumberland Fillbasket	Very dry berry ; good size and colour	Brown	Woody	Very firm berry.
Norwich Wonder	Firm berry ; good colour and size	Slight brown tinge	Not very marked	Good size ; firm berry.
Park Lane	Large Round berry	Very pale	Poor	
Goliath	Very small ; soft and juicy	Poor	Fair	Too soft for canning.
Pogson's Seedling	Small round fruit	Fair	Fair	
Red Antwerp (Laxton's)	Medium size ; fairly juicy; rather soft and dark colour	Brown	Fair	Rather soft and berries broken.
Herbert (Fell's)	Large round berry ; very light red in colour	Practically no red colour left in berries	Poor, woody	Good shape.
Bountiful (Laxton's)	Large berry ; rather conical in shape	Poor	Poor	Good shape and very firm berries.
Bath's Perfection	Small round berries ; bright red colour	Bright red syrup but berries very pale	Not much flavour	Medium size.

2. Gooseberries (Canning and Bottling).

In the processing of gooseberries for canning or bottling, it is necessary to remove the remains of the calyx and the stalk. This operation is known as "topping and tailing" or "snibbing." On a domestic scale the snibbing is carried out by hand, and the berries are usually preserved in water, owing mainly to the fact that they tend to shrivel when covered with moderately heavy syrup. On a commercial scale it is customary to do the snibbing by machine. The interior pan of this machine is roughened and revolves at a high speed, thus throwing the berries against the roughened surface, the tops and tails being removed and carried away by a stream of water.

When preserved in water, gooseberries are comparatively flavourless. Experiments were carried out to find a method of preventing the shrinkage of

the fruit when processed in heavy syrups. In these experiments it was noticed that the machine-snibbed berries did not shrink. Further experiments were carried out in order to ascertain :

1. If all the common varieties, when machine snibbed, could be processed in heavy syrups without shrinkage.
2. If there was any variety which—when " topped and tailed " by hand—could be covered with moderately heavy syrups without the berries wrinkling.
3. The most suitable strength of syrup to use in the canning and bottling of gooseberries to give the best flavour.
4. How to prevent wrinkling when hand-snibbed berries are covered by a heavy syrup.

The bottles (26-oz. commercial) of fruit were filled with cold syrup. They were sterilised by bringing the temperature to 165° F. in $1\frac{1}{2}$ hours and maintaining this temperature for ten minutes. The cans (nominal 1-lb.) were filled direct with hot syrup and sterilised at 212° F. for twenty minutes.

From the varieties which have been tested it appears there is no material difference in the preserving qualities of individual kinds of green gooseberries for canning or bottling. When the berries were machine-snibbed, they did not shrink when processed in heavy syrups. With all varieties shrinkage occurred when the berries were topped and tailed by hand and a heavy syrup used as the covering liquid. A syrup containing 4 to 5 lbs. of sugar to the gallon of water proved the most suitable for use as the covering liquid in canning and bottling gooseberries. It was found that blanching the hand-snibbed berries in hot water for varying lengths of time before processing did not prevent shrinkage in heavy syrups. In the machine-snibbing of gooseberries it was noticed that portions of the epidermis of the berry were removed ; fruit treated in this way always appeared mottled before processing. The removal of portions of this outer layer allows diffusion to take place more readily and thus shrinkage is avoided. An attempt was made to bring about the same effect during hand-snibbing, a portion of the outer layer of the berry being removed with the remains of the calyx and stalk. These berries did not shrink when covered with syrups containing 4 to 5 lbs. of sugar per gallon of water. To get the best results from the canning and bottling of gooseberries on a domestic scale it is advisable, therefore, to remove a portion of the outer skin of the berry when topping and tailing, and to use a syrup of the strength indicated above. In this way an excellent product can be obtained.

Variety.	Strength of syrup in lbs. of Sugar per gallon of water.	Hand or machine snibbed	Bottles or cans.	Result.
Early Sulphur	6	Hand	Bottles	Fruit badly wrinkled and risen in bottle.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Berries wrinkled very slightly, and risen slightly in bottle.
,,	3	,,	,,	,, ,,
,,	2	,,	,,	No shrinkage.
,,	6	Machine	Lac. can	No wrinkling ; excellent flavour.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Berries plump and sweet enough.
,,	6	Hand	,,	Fruit wrinkled ; flavour satisfactory.
,,	5	,,	,,	Berries wrinkled but not very badly.
,,	4	,,	,,	Very slightly wrinkled ; sweet enough.
,,	3	,,	,,	Not shrivelled, but not sweet enough.
,,	2	,,	,,	,, ,,
Whinham's Industry	6	Hand	Bottles	Berries badly shrivelled and risen in bottle.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	,, ,,
,,	3	,,	,,	Fruit slightly wrinkled and risen slightly in bottle.
,,	2	,,	,,	No shrinkage.
,,	6	Machine	Lac. can	Very slightly wrinkled.
,,	5	,,	,,	No shrinkage ; excellent flavour.
,,	4	,,	,,	,, ,,
,,	6	Hand	,,	Badly wrinkled and rather too sweet.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Slightly wrinkled ; excellent flavour.
,,	3	,,	,,	Not shrivelled, but not sweet enough.
,,	2	,,	,,	,, ,,
Lancashire Lad	6	Hand	Bottles	Fruit badly shrivelled and risen in bottle.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Berries slightly wrinkled and risen in bottle.
,,	3	,,	,,	,, ,,
,,	2	,,	,,	Excellent appearance but not sweet enough.
,,	6	Machine	Lac. can	Not wrinkled ; a little too sweet.
,,	5	,,	,,	Not wrinkled ; about sweet enough.
,,	4	,,	,,	Not wrinkled ; not quite sweet enough.
,,	6	Hand	,,	Many berries shrivelled ; too sweet.
,,	5	,,	,,	Fruit slightly wrinkled ; good flavour.
,,	4	,,	,,	,, ,,
,,	3	,,	,,	Not shrivelled, but rather acid.
,,	2	,,	,,	Not shrivelled ; not sweet enough.
,,	3	,,	Unlac. can	Tin attacked and feathery. and slight tinny flavour ; not sweet enough.
Keepsakes	6	Hand	Bottles	Berries badly shrivelled and risen in bottles.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	,, ,,
,,	3	,,	,,	Fruit slightly wrinkled, and risen slightly in bottles.
,,	2	,,	,,	No shrinkage.
,,	6	Machine	Lac. can	Small berries not wrinkled ; excellent flavour.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Small berries not wrinkled ; rather short of sugar.

Variety.	Strength of syrup in lbs. of Sugar per gallon of water.	Hand or machine snibbed.	Bottles or cans.	Result.
Keepsakes	6	Hand	,,	Small berries badly wrinkled ; too sweet.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Slightly wrinkled ; about sweet enough.
,,	3	,,	,,	Not shrivelled ; rather acid.
,,	2	,,	,,	,, ,,
White Lion	6	Hand	Bottles	Fruit badly shrivelled and risen in bottle.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Very slightly wrinkled and risen slightly in bottles.
,,	3	,,	,,	,, ,,
,,	2	,,	,,	No shrinkage.
,,	6	Machine	Lac. can	No shrinkage ; an excellent product.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	No shrinkage ; sweet enough.
,,	6	Hand	,,	Berries wrinkled ; good flavour.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Very slightly wrinkled.
,,	3	,,	,,	Not wrinkled, but rather acid.
,,	2	,,	,,	No shrinkage, but not sweet enough.
,,	3	Machine	Unlac. can	Tin feathered ; very slight tinny flavour.
Careless	6	Hand	Bottles	Berries badly wrinkled and risen in bottle.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Fruit slightly shrivelled and risen slightly in bottle.
,,	3	,,	,,	,, ,,
,,	2	,,	,,	No shrinkage.
,,	6	Machine	Lac. can	No shrinkage ; rather too sweet.
,,	5	,,	,,	No shrinkage ; good flavour.
,,	4	,,	,,	Berries plump ; barely sweet enough.
,,	6	Hand	,,	Berries very badly wrinkled ; good flavour.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Slight wrinkling ; not quite sweet enough.
,,	3	,,	,,	Not shrivelled ; but acid in flavour.
,,	2	,,	,,	,, ,,
Crown Bob	6	Hand	Bottles	Fruit badly shrivelled and risen in bottle.
,,	5	,,	,,	,, ,,
,,	4	,,	,,	Berries slightly wrinkled ; and risen slightly in bottle.
,,	3	,,	,,	,, ,,
,,	2	,,	,,	Berries not wrinkled and not risen in bottle.
,,	6	Machine	Lac. can	Excellent flavour ; very slightly wrinkled.
,,	5	,,	,,	Berries plump, and good flavour.
,,	4	,,	,,	Quite sweet enough ; excellent flavour.
,,	5	Hand	,,	Only about half the berries wrinkled ; good flavour.
,,	4	,,	,,	Many berries wrinkled. Excellent flavour ; sweet enough.
,,	3	,,	,,	Slightly wrinkled ; some berries not wrinkled at all.
,,	2	,,	,,	Not wrinkled ; not sweet enough.
,,	3	Machine	Unlac. can	Tin attacked ; fruit had a slight tinny flavour ; syrup slightly clouded ; not sweet enough.

ROYAL HORTICULTURAL SOCIETY,
VINCENT SQUARE,
WESTMINSTER, S.W.1.
11th June, 1926.

TO THE EDITOR, "JOURNAL OF POMOLOGY AND HORTICULTURAL SCIENCE."

THE JONES-BATEMAN CUP.

In 1920, Miss L. Jones-Bateman, of Cae Glass, Abergele, presented to the Royal Horticultural Society a valuable silver-gilt replica of the Warwick Vase to be used for the encouragement of fruit production. It is accordingly decided to offer it triennially for researches in the growing of hardy fruits, figs, grapes and peaches in the open or under glass, and it is available for award in 1926.

Candidates should submit accounts of their work by 31st October. The work dealt with must have been carried out by the candidate in the United Kingdom mainly during the past five years. The Cup will be held for three years by the successful candidate who must give a bond for its safe return, and when the cup is relinquished the holder will receive a commemorative gold medal. The holder will be eligible to compete on the next or any succeeding occasion.

The Assessors will be three, two appointed by the Royal Horticultural Society and one by the National Farmers' Union, and they will report to the Council of the Royal Horticultural Society upon the originality and comparative potential value to the fruit-growing industry of the work of the candidates.

The Council of the Royal Horticultural Society will award or withhold the Cup at its discretion.

A. SIMMONDS,
Assistant Secretary.

AN ENQUIRY INTO THE QUALITY OF ENGLISH GROWN WALNUTS.

By HOWARD SPENCE.

In an earlier issue of the *Journal* some notes were given on nut growing in the northern United States.* Attention was drawn to the very large increase in acreage of walnut groves in the north-western States during the last twenty to twenty-five years and the view expressed that this country could do much more, and better, work in meeting the home demand both for fresh and dried walnuts. It was however realised that systematic investigation into some of the factors involved was essential before wider planting could safely be advocated. These include a study of the best stocks for this country—on the continent the common walnut, *Juglans regia*, in the eastern United States the black walnut, *J. nigra*, and in the western States the California black walnut, *J. californica*, var. *Hindsii*, being variously employed—the location of the best types now growing here, and an investigation into the possibility of acclimatising good foreign varieties.

There is sufficient warrant in continental and American practice to assume that the stocks question will not afford serious difficulty. The black walnut takes *regia* scions freely and the common walnut has itself a number of varieties with very good growth vigour. More difficulty will be experienced in finding native varieties for propagation which already come up to the required standards of good quality nuts, and in ascertaining which of the best foreign varieties will retain, more or less unimpaired, their qualities under our climatic conditions. Breeding work must come as a later stage following the identification of the best material. A combination of as many as possible of the following points is required: uniform fairly large size and good light colour, regular contour, moderately stout shell and good sealing; the nuts after drying should be well filled, plump, non-astringent and, above all, have the typical true rich walnut flavour free from all woodiness—not merely crisp and palatable in the fresh condition. The ripe undried nuts must not contain excessive moisture and the parent tree should give a good and reasonably regular crop.

Size.

Good continental and Californian walnuts weigh, in the dried condition, from about 10 to 14 grams. The size of different types may vary between the extremes of the French Noix noisette or so-called *Juglans regia* var. *microcarpa* with a weight of 2 or 3 grams and the walnut, weighing up to 15 grams, known in

* *Journal of Pomology and Horticultural Science, Vol. IV., No. 1*, July, 1924.

France as Noix à bijou (*J. r.* var. *maxima*) and in this country as Bannut, Barnut, or double walnut. Only if large size is accompanied by other good qualities is it an advantage and this is rarely the case here. Seedling trees of the Bannut type are very commonly grown up and down the country and although the nut, in appearance, is frequently very attractive it has otherwise little to recommend it. The California Walnut Growers' Association which disposes of an annual crop of some 20-30,000 tons, has the following size standard. Walnuts passing through a square hole of $1\frac{3}{16}$ in. side, and retained on a $1\frac{1}{2}$ in. hole form the "standard budded" nut, or No. 1 grade. Those retained on the $1\frac{3}{16}$ in. mesh command a higher price. Typical high quality French nuts such as Franquette, Parisienne and Mayette, weigh between 10 and 12 grams and the well-known Italian Sorrento walnut about the same. An average length of these nuts is about 1.5 inches with a thickness (at right angles to the sutural plane) of about 1.23 inches. Typical Californian walnuts such as Placentia, Eureka, Ehrhardt, Lucretia and Grove weigh about 12 to 14 grams and have an average length of about 1.65 inches and a thickness of about 1.378 inches.

Colour.

Walnuts of different varieties may vary from a dull brown to a light or yellowish brown or tan colour, some showing a somewhat greyish tint. In California the nuts are largely bleached by passing through a dilute hypochlorite bath, but this is more to remove the staining caused by more or less prolonged contact on the ground with the exocarp, where the latter rapidly softens and stains the outer shell, than to modify the natural shade. The original usually attractive colour of the shell can largely be preserved by the removal of the husk as early after falling from the tree as possible. This also reduces the liability to development of mould.*

Contour.

The form of the nut may vary considerably from the typical symmetrical slightly elongated oval with rather flattened base and somewhat pointed apex to a decidedly conical or a broad and flattened type. Uniformity is very desirable in any one variety. The shell should be comparatively smooth, not irregular or deeply pitted or corrugated and the sutural ridges not unduly prominent.

Thickness of Shell.

A reasonably stout shell capable of withstanding commercial handling without material breakage is essential in a good nut. The thickness may vary

* See "Methods of Harvesting and Irrigation in Relation to Moldy Walnuts," L. D. Batchelor, Bull. 367 California Agricultural Expt. Station, 1923.

between little more than stout paper thickness in the French Noix à mesange and over one-eighth of an inch in the wild Himalayan walnut. Standard French and Californian walnuts have shells of about 0.1 to 0.15 cm. (0.039 to 0.059 inch) in thickness. Shells of this character crack readily—with a crushing stress of about 40-70 lbs. In the majority of English nuts so far examined the shells are rather thin.

Sealing.

Tightness of sealing is a very important point in a good quality nut and this usually goes with some stoutness of shell. If the nut shows a tendency to open on being pressed moderately between finger and thumb about midway on the sutural ridge it will not in most cases be a good keeper. It is necessary that the nut should be capable of being dried without any tendency to open. The best continental and American varieties have a reasonably stout shell that will withstand repeated handling and one thoroughly well sealed. Most English nuts are weak in the latter respect.

Percentage of Kernel.

This should average 45-50 per cent. of the weight of the dried nut. The kernel should be plump, well formed, unshrivelled, should fill the shell well and have an attractive colour and appearance ; the colour of the pellicle may be light tan, light or silvery brown or straw colour. Dark or bright yellow kernels are not desirable. As indicated later the large majority of home-grown walnuts show seriously shrivelled kernels after moderate drying.

Astringency.

In some varieties the pellicle of the kernel is very astringent and may spoil the quality of an otherwise good nut. It is essential that the unpeeled kernel should be practically free from this defect. The astringency is more marked in the fresh undried state in some nuts, in others after drying.

Flavour.

This is of course the most important feature of the nut. It is not enough that the walnut is crisp and palatable in the fresh milky condition—given freedom from astringency and woodiness in flavour, both of which unfortunately are not uncommon characteristics, many of the walnuts grown in the country would conform to this standard—nor even that the nut contains a reasonably high percentage of oil, another feature in which many of our walnuts are deficient.

The prime essential is the possession of the typical flavour of the best continental or Californian walnuts, rich, mild, sweet (not sugary) and essentially nutty. The question of oil content of the kernel is later dealt with in more detail.

Percentage of Moisture in the Freshly Gathered Nuts.

The normal amount of moisture in this condition is about one-third of the weight. The total amount of water in Californian nuts as harvested averages about 30 per cent. and may vary from about 35-45 per cent. towards the end of September to about 16-20 per cent. in early October. After sun-drying or dehydration the average residual moisture is about 6 per cent.* The plump, unshrivelled character of the kernel after drying and containing, in this condition, from about 56 to 63 per cent. oil, indicates that shell moisture must account for the major portion of this water. Any excessive proportion of moisture in the kernel of the walnut as gathered must inevitably lead to undue shrinkage of the kernel on drying.

Crop Yield.

Under Californian conditions the walnut is normally planted in groves carrying about twelve to twenty-seven trees to the acre ; the former number, equivalent to 60 feet apart on the square system, is considered to be the best practice. Competently managed the crop may be expected to average 1,200 lbs. and, exceptionally, up to 2,000 lbs. dried nuts per acre per annum. In France, on the contrary, the major portion of the crop is derived from isolated trees scattered throughout the vineyards, wheatfields and borders and the crop may be anything up to about 400 lbs. from a very good tree. The crop yields so far recorded from English trees indicate quite good prospects on this score.

In any effort to improve upon the general average quality of the walnuts now grown in the country an examination, so far as possible, of the very large number of existing trees (practically the whole of which are seedlings) is essential to ascertain what really promising material we may already possess and also the nature of the difficulties likely to be met.

The basis of a preliminary survey was discussed between Mr. H. V. Taylor, Deputy Controller of the Horticultural Division of the Ministry of Agriculture and Fisheries, Mr. R. G. Hatton, Director of the East Malling Research Station, and the writer, and with the help of the Ministry's Inspectorate staff and of others who kindly afforded assistance, a preliminary collection of walnut samples from trees growing in some twenty-five counties was made in the

* Bull. 376 Agricultural Expt. Station, California, 1924.

autumn of 1924. The results of this enquiry and its continuation last year, with some extracts from the classification records of the nuts received, are outlined below. The detail of the reports made to the Ministry is necessarily much abbreviated, but the summary given suffices to show the difficulty of finding good quality walnut varieties among our chance grown seedling trees which are capable, under the average summer temperature conditions and the relatively low sunshine intensity of the British Isles, of developing, even in the central and southern counties, the normal oil and moisture content of a good ripe walnut—upon which its value and keeping quality are primarily dependent.

Nuts from some one hundred and sixty walnut trees, together with particulars in more or less detail relating to the parent tree, were forwarded by twenty-eight contributors between the end of September and beginning of December in response to the request for samples, accompanied by a questionnaire, sent out by the Horticultural Division of the Ministry in August, 1924. One or more were received from the following counties:—Bucks., Dorset, Essex, Glamorgan, Gloucester, Hants., Hereford, Herts., Kent, Leicester, Lincoln, Merioneth, Monmouth, Montgomery, Norfolk, Northants, Notts., Oxford, Salop, Stafford, Surrey, Sussex, Warwick, Worcester, Yorks.

The very poor keeping qualities of by far the majority of the walnuts received in this year necessitated, in the earliest stage of the enquiry, a decision as to the determination of their value in the fresh milky condition in which they are now always sold, or after a preliminary partial drying. While considerable variation may be found in the fresh nuts from the point of view of flavour, astringency, more or less complete filling of the shell, colour and other points, these differences are much less in degree than are shown between the nuts from different trees after drying. For the reasons given below the relative value of the nuts in the former state was held to be of considerably less importance than their qualities on keeping, and the classification therefore (while including notes on their condition as gathered) has been mainly confined to the partially dried walnuts. Their behaviour on drying affords the most reliable general test of quality readily available for walnuts grown in this country.* The object of the enquiry being to locate the most superior varieties of walnuts now growing in this country with a view to their propagation and distribution in gradual replacement of the variable seedling tree, no types can be considered really satisfactory, even if of fair quality in the fresh state, unless they are capable of being kept at least a reasonable time under ordinary conditions.

* Walnuts, commercially, are dried in two ways: by exposure in trays during the warm hours of the day to sun-heat, or by a current of heated air in mechanical dryers. Details of the two methods, the latter of which is tending to replace the former in the United States, are to be found in Bull. 376 of the California Agricultural Expt. Station, March, 1924. "Sun Drying and Dehydration of Walnuts," L. D. Batchelor and A. W. Christie.

If home-grown walnuts are later to displace foreign imports to any considerable extent it is essential that they possess qualities closely approximating to those from abroad—in addition to the advantage they retain of being available as fresh nuts.

A large dealer in a northern wholesale fruit market reports that there is very little sale for English walnuts owing to the damp condition of the nuts (in which condition they are very apt to develop mould) and the necessity of practically immediate consumption. Another stated that for a hundred bags of foreign walnuts a few only of English walnuts would be sold. On the other hand a number of reports from contributors of walnut samples are to the effect that there is a ready *local* sale for the fresh nuts ; this is especially the case where the reputation of a particular variety is good. In a few places however the crop is hardly considered to pay the costs of handling : 3d. or 4d. per lb. is a common price in local markets. The demand would obviously be stimulated, and the prejudice against the home-grown product in wider markets gradually overcome, by the ability to procure regular supplies of walnuts which have the advantage of being good nuts as gathered and also on keeping. These considerations were reinforced by the fact that a few, at least, of the samples first sent in gave clear indication that some varieties already possess keeping qualities of distinct promise.

If, as is essential, the enquiry be continued over a period of some years it will be possible to investigate more closely the cause of the present general very poor keeping quality. It is already apparent that this is directly associated with a deficiency in the normal proportion of oil in the kernel. The season of 1924 was very unfavourable generally and undoubtedly accentuated this defect, but it is clear that the majority of English walnuts, which are of very poor average quality, are normally below the standard in this respect. Those few which have a really rich true walnut flavour, are well filled, plump and attractive in kernel, and largely retain these qualities on moderate drying, are those in which the original percentage of oil is high. On the contrary the kernels of those deficient in oil are lacking in a really distinctive walnut flavour. When in the fresh condition they are frequently very palatable, crisp and milky, but in many cases have an unpleasant woody taste, are often astringent and lacking in flavour and, on moderate drying, shrivel to a tough, leathery and quite inedible caricature of a kernel.

The poor weather conditions of 1924 contributed to the deterioration, and to the rejection in classification, of a number of varieties which in normal years have a good local reputation. Owing to excessive rainfall and little sunshine the shells in a large number of cases developed very poorly. In many samples more than half of the nuts were perforated close to the apex and mid-way between the sutural ridges ; in others the shell was lacking from a

small extent up to more than half the surface* and the nuts dehisced badly. These defects are fully appreciated only after partial drying. A number of reports comment on the unfavourable effect of this season on the development of the nut :—

" Crop lighter by far than normal." (B. 20, a.)

" It appears to be agreed malformation is much more general this year than is usual." (G.T.)

" The walnuts this year on the above tree (F.9) are very poor in quality, most of them have not filled owing to wet season ; a very light crop. Most years it bears a heavy crop of excellent quality."

" In normal seasons this nut (E.9) is highly esteemed for its size and flavour and sells well, it crops freely. This season by far the worst on record, owner seventy years of age. Owner reports nuts this year are much smaller than usual. . . . Owner reports (E.10) nuts are only half size this year. . . . Only very moderate crop (E.12), approximately 2 cwts., usually crops heavily in good season."

" No. 14. Good all round in *dry* season, but in wet season no good for keeping and scarcely any kernel."

" Unfortunately the crop on these (nine fifteen-year-old trees) has been very poor this year." (N.J.W.)

" The agent told me that it was the worst season he had experienced for the last twenty-five years. Some of those he considered the best varieties have produced a useless nut—inside rotten, or the shell poorly developed." (D.G.M.)

The moisture in our walnuts as gathered is high and usually exceeds the normal 20-40 per cent. of the best type commercial nuts. In some cases in 1924 the loss on partial drying amounted to from 40 to 66 per cent., and a few also in 1925 have figures nearly as high ; this excessive content of water is particularly evident in walnuts of the Bannut type. It must also be borne in mind that these percentages do not give *total* moisture, but simply represent the loss in weight found by exposure for about ten days, in a single layer in trays formed of thin wooden strips $\frac{1}{4}$ inch apart, to a room temperature varying from 60°-65° F. during the day and falling to about 55°-60° F. at night : or approximately equivalent to standing exposed to ordinary indoor conditions. Under these conditions the nut still retains about 12-13 per cent. moisture in the shell and 5-6 per cent. in the kernel, or about 10 per cent. of the total weight on the average. The

* Perforation (including the non-development of the outer shell) has been a somewhat serious trouble in California in recent years. Curiously enough it there appears to be associated with unusually *dry* seasons. It has also been attributed, in the case of young trees, to vigorous development of wood at the expense of the nuts. Bull. 231, Agl. Expt. Station, 1912.

total residual moisture content in the partially dried nut is shown, in cases where oil percentage is determined, in Appendix A. In these cases the moisture in the kernels has been found by drying at 100° C. in a current of dried coal gas to prevent oxidation of the oil and that in the shells by drying in an ordinary air oven at 100° C. The percentage of oil was determined in the thinly sliced dried kernels by extraction with ether.

The general appearance of the nut (colour, size and uniformity) has a much closer relation to its selling value, under *present* conditions, than its intrinsic quality. This may be illustrated by the case of E.22. This type (a "double" walnut or "Bannut") is grown on two trees, very closely alike in quality, in Gloucestershire, giving crops of 1½ cwts.—4 cwts. per tree and, in appearance, is a peculiarly attractive type of *Juglans regia*, var. *maxima*. In a good year the nut weighs, *as gathered*, some 40 grams, or 10-12 to the lb., and is of excellent colour, contour and size. For some years the excess crop over home requirements has been sold to a fruiterer at 1s. 3d. per lb. ungraded, or 1s. 6d. graded. Internally, however, the nut is typical of a variety generally recognised to be lacking in the better qualities. In the fresh condition the kernel forms only 23 to 25 per cent. of the total weight, the flavour, although it is fresh and crisp, is rather poor and lacking in distinction, the nut will not keep under ordinary conditions owing to its high percentage of moisture and the excessively pulpy condition of the dissepiments with consequent tendency to mould, and when dried, is shrivelled and valueless. There are a few named varieties of *J. r.*, var *maxima* of superior character, e.g., Gourlande (largely grown in the district of Puy-de-Dôme, France, for use in the milky condition in confectionery), Alpine Mammoth and Willson (United States), but generally this type is highly deceptive in appearance and could perhaps be of most service in breeding work in contributing its quotum to a better strain. Apart from its general type characteristics the poor quality, in this particular case, as in others, is clearly due to excessive wateriness and to deficiency in oil: the fresh kernel contained about 9 per cent. only and 17.58 per cent. in the kernel dried at 100° C. It is interesting to note the improved quality of this nut in the more normal season of 1925.

Another extraordinarily large nut (Appendix A—H.E.D.) showed very much the same general characteristics. It averaged, in the few samples available, 2.5 inches in length and weighed 25.3 grams when in the fresh condition, was filled by the kernel for only one half to two-thirds of its length, and contracted seriously on drying. As received it contained from 31- 42 per cent. kernel, but the latter, on fully drying, weighed only 2.53 grams and contained, in this condition, 12.4 per cent. of oil.

From the foregoing it will be appreciated that the writer's opinion on the general quality of a nut is based on a standard differing, in many cases, from that of the contributor valuing the nut from the point of view of its fresh condition

only. This latter standpoint deserves attention, but in view of the possibility of combining the advantages of good quality in both the fresh and dried condition it should be largely discounted in the present enquiry. Opinion will be found to vary widely on the characterisation of the nut as gathered: there is much less room for difference when the partially dried nut is examined.

The value of the common type of English walnut exposed for sale is greatly lessened both by poor colour (largely avoidable as indicated earlier) and by the small average size. Irregularity in size will of course always be present to some extent and can only be corrected by grading—a very simple matter compared with that of other fruit as the nut suffers no degradation by handling without special care—but a large nut has, on account of size alone, the highest selling value. Home grown walnuts have not so far been of sufficient importance to inculcate a discriminating choice in the demand, but there is no reason why good size should not be accompanied by good quality. As originally requested in 1924 nuts were sent in almost promiscuously and, in spite of hopeless character in many cases, were graded uniformly and recorded, but in the continuation of the enquiry last year one or two preliminary tests were suggested by which the Ministry's Inspectorate staff and others weeded out those having no prospect of contributing any factor of real value for the purpose in view. In an extension of the enquiry both over untouched areas and those from which a few samples only have been drawn, the classification of a large number of types must involve considerable time and it is desirable to concentrate on the most promising.

Another important fact revealed by replies to the questionnaire is the very satisfactory yield from individual trees. In 1924, a year unusually unfavourable, crops of from one to four cwts., per tree were commonly reported and, in one case, ten cwts. These weights are, of course, those of the fresh nuts as gathered and should be reduced by about 40 per cent. for comparison with continental or Californian figures. There is nothing to be feared on this point with good trees in normal seasons. More evidence is desired as to regularity or otherwise in bearing.

The close relation between the proportion of oil originally present in the nut and its keeping qualities is unmistakable. In a number of cases, where the latter were above or well above the average, analyses were made of the kernels in the dried condition and uniformly confirmed this conclusion. *Per contra,* tests made with walnuts showing much shrinkage gave low percentages. It remains to be proved how far this is an inherent character of a poor type of nut or whether it is materially influenced by environment and soil conditions. The seasonal factor is clearly of considerable importance, some varieties being more adversely affected in this respect than others. The percentage of oil is known, apart from variable conditions, to vary somewhat in different French types and this probably holds to a much greater extent in this country with its lower

summer temperatures. The earliness or lateness of fertilisation (this may vary by four to six weeks) may have a greater influence in this country than abroad. In a large number of cases the absence of any richness in the flavour, indicative of oil deficiency, was accompanied by unusual and excessive sugariness ; this might suggest the non-completion, in a year deficient in sun heat and light energy, of the physiological processes of the plant by which the oil is normally produced.

To enable a comparison to be made with standard foreign walnut varieties, Eureka, Ehrhardt, Placentia, Lucretia and Grove walnuts (California), Sorrento (Italy), Parisienne and Mayette (France), and some Australian walnuts have been analysed. The percentages of both kernel and oil in these nuts are high : the thickness of the shell is substantial, and the total weight and size, the tight sealing and general contour, colour and flavour give them the high reputation they hold in the countries of their origin.

Of the seventy odd samples of walnuts which have been chemically analysed during 1924 and 1925 it is possible only to give a few indicating differences of interest—see Appendix A. Among our own nuts F.1. illustrates the character of an unfortunately large proportion of the walnuts received in 1924, i.e., those showing hopeless deficiency in kernel and in oil. E.22 was selected as representative of the average very large double walnut of that year, of which H.G. and E.3 are much better types. B13X and C1, although having too low a percentage of kernel, are much better for oil. E13 represents a type of nut, of which many were received, containing an abnormally high water content—in this case, under normal drying, two-thirds of the original weight being lost. Excessive shrinkage is inevitable in such cases. E.18 is a nut in which sugariness is the predominant feature ; it should be tested again in a more normal year. No. 11, although a very small nut of its type, is distinctly of the " Bannut " character, but of better than average quality, with an exceptionally good rich fresh flavour ; and C.14 (*a*), a small nut of the ordinary type, also promises well : its percentage of oil was the highest found for the year. Nos. 2, 4 and 5, and C7 were selected as representative of the distinctly promising types which, even in a poor season, contained a high kernel and oil proportion on drying.

In comparing the varying percentages of both kernel and oil it must be borne in mind that the dry weight of the nut was frequently only about half, or even less, that of the original and consequently what appear to be moderately high percentages may represent very small actual weights—and the proportion of kernel also be unduly high owing to lack, or extreme thinness of shell in 1924.

The season of 1925 was generally much more favourable to normal walnut development and this fact, coupled with the higher standard indicated in the

revised questionnaire distributed by the Ministry, resulted in decidedly better quality samples being forwarded for examination.

The following additional counties were represented among the ninety-two home-grown samples received: Bedford, Cambs., Cornwall, Devon, Huntingdon, Middlesex, Somerset, Suffolk and Wilts.

The general improvement due to better seasonal conditions is particularly noticeable in a re-examination this year of a few of the 1924 samples. E.22, for example, gave in that year a kernel (fully dried) with 17.58 per cent. oil, last year one with 54.53 per cent.; in the former year 25 per cent. of the nuts of C.17 were malformed, this year malformation was absent, and others showed similar improvement in differing degree.

On the evidence of 1924 it was considered that the percentage of walnut oil in the nut was one of the most important factors in determining its quality and this is confirmed by later tests. More than half of the total number of the samples from this year's crop have been analysed for oil percentage, and of these 12 per cent. showed more than 60 per cent. oil in the kernel, dried at room temperature, 43 per cent. between 50 and 60 per cent, 33 per cent. between 40 and 50 per cent., and 12 per cent. between 30 and 40 per cent. The forty-nine analysed included practically all the nuts with any point of merit, and the grades with low oil percentage would of course represent a much higher actual proportion of the whole. These analyses prove that on the score of oil percentage only, there are a number of walnuts which meet the necessary standard.

In stressing this point however, perhaps insufficient weight was attached to another factor second only in importance, i.e., the original proportion of water present in the fresh kernel or, in other words, the necessity for a high percentage of oil in the nut as gathered. It would be desirable in another season to differentiate more closely between shell and kernel moisture in the fresh nut. but that a high proportion of the total must originally be present in many cases in the kernel is indicated both by the very watery and poor flavour of so many of our home-grown types, and by the excessive shrinkage shown in the kernels on partial drying. It is therefore not enough that the ratio of oil to protein and carbohydrates* in the dried walnut kernel should be normal, but also that in the fresh undried condition the total of these bodies shall be high in relation to the water content. Where the latter is reasonably low the chances of good quality will be much enhanced.

The protein and carbohydrates have been determined in three typical samples—(*a*) B.L.W.—2, of which the poor and sugary flavour and low oil

* Jaffa (Nuts and their uses as Food, Farmers' Bulletin 332, U.S. Dept. of Ag., 1910) gives the following walnut analysis :

Water.	Protein.	Oil.	Carbohydrates.	Ash.
3.4%	18.2%	60.7%	16.0%	1.7%

content are characteristic of the majority of existing English walnuts; (*b*) G.C.M.—1, in which the factors are very close to those desired but for the presence of excessive moisture in the fresh kernel; and (*c*) J.M.W—P.12, in which (although the sample was received a couple of months after gathering and the fresh condition therefore, in relation to moisture, could only be inferred), the still very attractive and plump kernel indicated an original reasonably low kernel moisture, and which, in flavour and otherwise, approximates very closely to the desired standard. The complete analyses are :—

	B.L.W—2.	G.C.M.—1.	J.M.W.—P12.
Water	7·09%	6·51%	5·74%
Walnut Oil	35·10	58·89	59·28
Protein	14·87	16·62	17·06
Carbohydrates	39·99	16·01	15·04
Ash	2·95	1·97	2·88

The figures largely explain the differences actually found in the flavour and palatability of the different types. The suggestion, arising from the 1924 survey, that the undue sugariness of so many walnuts might be due to the non-completion of the physiological processes of the plant by which, during ripening, the gradual formation of the final components in their proper proportion are brought about, would seem to be supported by these comparative analyses. In B.L.W.—2, where sugariness is a marked feature, the percentage of carbohydrate is excessive, apparently at the expense of the oil, the protein also being a little low. G.C.M.—1, which, as indicated, was of good flavour, shows a nearly normal ratio between carbohydrate, oil and protein although carrying too high a proportion of water. Whether the woody flavour, so frequently noted, is due to the presence of ligno-cellulose as an incompleted stage in the formation of the oil content of the nut, is a point for further investigation.

As illustrative of the general character of the walnuts received in 1925 the following have been selected from among the analytical results and included in Appendix A. E.22 may be compared with E.26, which, although analysing very similarly, is of a distinctly better type. B.L.W.—2 has been referred to as representative of the incompletely developed nut in which sugariness is excessive, a common fault in both years. H.S.—1, C.K.M.—1 and G.F.—1 draw attention to the important fact that while analysis is a helpful guide to quality, promising figures may be found for a nut of which, as in these cases, the somewhat woody or otherwise poor flavour is not compatible with really good quality. As a rule, however, woodiness goes with too low a proportion of oil in the dried nut. A number of walnuts in 1925 have given very good oil percentages after drying, and several, in addition, have qualities of distinct value (amongst other B.M.S.—B, W.S.M.—1, C.P.N.—1 and W.C.P.—1 may be cited in this connection), but the essential practically unshrivelled and

attractive looking kernel, coupled with full walnut flavour unmarred by woodiness or undue astringency, is lacking in all but one or two. On dry kernel percentage G.C.M.—1 would be placed low but it nevertheless is a nut with very valuable points warranting its inclusion in the list ; C17 also has a very promising flavour.

The walnut which, on present evidence, most closely approaches the desired standard is J.M.W.—P.12. The attention of the owner was not drawn to the enquiry until some couple of months after the crop of the tree had ripened (in mid-September, in itself a valuable feature provided flowering is not also so early as to subject the tree to frost danger), and a few nuts only had not then been given away. As received these were unusually attractive in colour and well filled, the colour of the kernel also being very good. The flavour was the closest approach to that of a typical rich continental or Californian walnut of any home-grown variety so far tested ; the nut was well sealed on the whole and is reported to be of much better size than the few remaining nuts might indicate. The tree is estimated to be twenty to thirty years old, and the crop at about two bushels.

G.C.M.—1, to which previous reference has been made, although defective in the proportion of kernel and showing a high loss on drying, had also an unusually good flavour in the fresh condition and kept much better than the average nut on drying. It would form a very desirable garden walnut and is one of the most prolific types reported, with a normal crop of about eight cwts. This year it was fourteen cwts. and in an earlier year has been forty-five bushels. Even after deducting about 40 per cent. for moisture loss from these weights, the yield is extraordinarily heavy. This tree, estimated to be about 200 years old, has also been considered deserving of propagation trials. It is an attractive relatively small nut of the Bannut type, unusually constricted along the suture line, giving it a curiously "waisted" appearance. A considerable number of the varieties forwarded in 1925 were of the *maxima* type—most of them of the usual poor quality. In California *very* large size is not considered a desideratum, but here with, it must be confessed, less discrimination, English "doubles" may sell in Covent Garden at 11d. to 1s. 1d. per lb., as compared with 7d. to 8d. for ordinary English walnuts, when at the same time better quality French walnuts are selling at the equivalent of 5d. to 6d. per lb. It is evident there is a market, although at present relatively restricted, capable of being worked up for the best types of home-grown walnuts. In view of the marked preference shown in the home market for a large walnut arrangements will be made to introduce and test under English conditions one or two of the best American varieties of this type which are, at least in their own country, much better than any of ours so far reported or than the French Gourlande variety which, in 1925, analysed very badly.

Little or nothing is yet known of the effect of soil conditions on the crop. Californian experience on the effect of fertilisers on crop yield, in a triple series of experiments extending over a period of six years under varying conditions, has been quite indeterminate, but it remains to be proved whether the presence or absence of certain soil constituents may affect the composition of the walnut kernel in this country or whether the differences found are mainly due to type variation. There may or may not be some connection between the good quality J.M.W.—P.12 and the fact that the burnt garden rubbish is dug in around this tree.

As a preliminary standard test to determine the presence or otherwise of the essential qualities of promising types of walnuts nothing perhaps could be simpler than to ascertain if they retain an attractive and practically unshrivelled kernel after exposure, in a single layer, to living room temperature for ten to twelve days. The walnuts passing this standard will be a very small proportion only of the whole, but it is essential either to find varieties which will meet this condition or to introduce them from abroad. With this as a foundation further discrimination can then be exercised between other points of importance. A dozen located types can already be indicated which would be a great improvement on the large majority of walnuts in the country, but the writer does not consider any, with one exception, yet merit a wide general distribution, except perhaps for home consumption. Among these are one or two varieties excellent for home use but too small for the market. The proportion of walnuts which has been found to have the full typical flavour of a good walnut is extremely low.

The total number of samples yet tested in both years is, however, so small a fraction of the available seedling trees that the probability of finding better varieties is strong if the co-operation of owners generally can be secured. We have not California's wide choice of material (the horticultural census of 1910 gave a million and a quarter seedling walnut trees—the transition period from seedling groves to grafted tree plantations largely setting in about this time) but the many thousands of our seedling walnuts also afford good hunting ground. The information already gained proves beyond doubt the possibility of growing walnuts, in the midland and southern counties at least, which have the qualities essential to enable them to compare favourably with continental types. That all the desired features have not yet been found fully combined in any one variety is, with the limited field so far covered, not surprising. The factors of good colour, size, contour, percentage of kernel and of oil, flavour, sealing, crop yield and absence of astringency and excessive moisture have all been found variably associated in a number of the varieties examined : what is still required is their more or less complete association, allowing for individuality of taste, in half a dozen varieties.

It is definitely established, as a result of prolonged continental and Californian experience that no reliance can be placed upon the quality of seedling walnut trees. Walnut seedlings are almost as variable as those of apples and therefore must equally be propagated asexually. Concurrently with the endeavour to locate our existing best types experimental work is proceeding, principally at East Malling, on the subject of stocks and their standardisation, the best methods of propagation for our conditions and also to determine the quality of walnuts grown here from the best foreign grafted varieties. Scions from some of the best varieties have been obtained from California and Italy, and valuable material has already been produced for later comparison under British conditions with known results abroad. The gradual replacement of the seedling tree by proved varieties of much superior quality will, it is hoped, thus become a practicable proposition, in addition to the possibility of working over, as is largely done in the United States, comparatively young trees to such varieties. A large number of good quality walnuts from India, Persia, China, Algeria, Czecho-Slovakia, California, Canada and France, have also been planted to obtain seedlings from which it is expected a number at least of good type seedlings may be selected for propagation purposes in later years.

The co-operation of all owners or anyone knowing of walnut trees of exceptional merit which may offer the prospect of giving an already acclimatised walnut to British horticulture will be valued. To be of most service this should take the form of a sample of the nuts which in the opinion of the owner reasonably meet the standard indicated in Appendix B, together with the relative particulars. One or two grafted trees of all individual types which are considered to be promising subjects for propagation will be supplied by the East Malling Research Station to the contributors in order to ensure, in the first instance, perpetuation of the desirable variety in its original home.

These notes are published at the suggestion of the Ministry with the object of enlisting assistance in the enquiry and the writer desires to thank the many contributors of walnut samples for examination together with the particulars relating to the parent trees, and also those who have very kindly gone to much trouble in forwarding seed walnuts and scions.

Copies of the notes and questionnaire in Appendix B will be forwarded for completion by anyone interested on application to the Horticultural Division of the Ministry of Agriculture and Fisheries, 10, Whitehall Place, London, S.W.1.

Appendix A.

Analytical Results, 1924.

	No.	Wt. of nut grms.	Kernel %	Moisture at 100°C Shell %	Moisture at 100°C Kernel %	Oil in normally dried kernel %	Oil in kernel dried at 100° C. %
	F1	2.1	17.3	22.11	36.00	4.90	7.65
	H.G. ..	10.3	36.4	13.56	6.50	35.51	37.97
	B13X ..	8.02	32.0	12.49	5.74	44.38	47.08
	C1	5.1	32.36	13.42	6.28	42.87	45.74
	E22	9.7	32.0	14.71	11.30	15.60	17.58
	H.E.D. ..	7–13.7	31.7	17.31	34.0	8.20	12.42
	E13	4.78	30.74	14.41	9.25	20.85	22.97
	11	6.0	—	—	4.00	45.50	47.3
	E3	10.3	—	—	2.53	43.52	44.6
	2	7.57	55.7	10.80	3.22	50.20	51.8
	4	11.25	—	—	4.49	53.02	55.51
	5	10.25	40.6	14.74	5.00	53.50	56.31
	C7	6.63	—	—	4.51	48.70	50.9
	C14(a) ..	6.73	50.0	12.51	4.62	58.25	61.07
	E18	4.41	—	—	8.35	30.08	32.82
California	Eureka ..	14.0	45.6	16.16	4.58	59.47	62.32
California	Ehrhardt ..	14.3	49.7	11.63	4.56	56.72	59.44
California	Placentia ..	12.55	44.9	11.01	3.63	57.47	59.63
California	Lucretia ..	13.18	42.47	12.62	4.69	63.86	67.00
California	Grove ..	13.7	48.9	12.50	4.24	63.33	66.13
Italy	Sorrento ..	10.5	48.1	11.90	3.65	62.05	64.40
France*	Parisienne ..	10.55	41.63	14.57	4.25	60.55	63.23
France*	Mayette ..	10.3	41.75	11.55	4.37	56.75	59.34
	1925.						
	E22	8.975	37.28	11.49	5.38	51.6	54.53
	E26	13.340	39.55	12.12	4.98	51.38	53.51
	B.LW—2 ..	7.138	29.56	11.35	7.09	35.10	37.77
	HS—1 ..	9.248	41.05	13.62	5.52	61.13	64.70
	CKM—1 ..	8.665	36.91	12.51	5.80	56.68	60.17
	GF—1 ..	8.315	42.19	14.81	5.67	59.45	63.02
	BMS—B ..	9.593	47.97	13.11	4.55	63.85	66.89
	WSM—1 ..	8.155	55.46	17.97	4.84	59.52	62.55
	CPN—1 ..	7.412	53.43	12.93	4.79	62.27	65.40
	WPC—1 ..	9.216	42.91	13.17	4.97	61.30	64.51
	GCM—1 ..	12.312	32.95	13.86	6.51	58.89	62.99
	C17	7.088	43.16	13.28	5.76	57.84	61.38
	JWM—P12	7.685	46.17	14.38	5.74	59.28	62.89
Australia	969	12.478	46.00	12.64	4.59	58.45	61.26
Australia	770	10.142	44.81	12.41	5.90	62.12	66.01

* The French nuts were hardly up to the normal standard in 1924.

APPENDIX B.

Walnut Survey. Ref. H.C.721.

A walnut variety which is considered by the owner or contributor to be worth examination should be preliminarily tested by him in the following way—*one or two lbs. of the variety meantime also being put aside in a cold cellar or outhouse for despatch if the nuts tested appear to reach the desired standard.*

FULLY EXPOSE TWO OR THREE DOZEN WALNUTS, IN A SINGLE LAYER, TO THE TEMPERATURE OF A LIVING ROOM FOR TEN DAYS. IF THE MAJORITY OF THE NUTS WHEN CRACKED AT THE END OF THIS TIME SHOW A PLUMP PRACTICALLY UNSHRIVELLED KERNEL THE VARIETY IS WELL WORTH EXAMINATION AND NOT LESS THAN ONE LB. OF THE UNDRIED WALNUTS PUT ASIDE SHOULD AT ONCE BE FORWARDED. IF, ON THE OTHER HAND, THE EXPOSED WALNUTS ARE FOUND TO SHOW LARGELY SHRIVELLED KERNELS THEY DO NOT REACH THE MINIMUM STANDARD DESIRED FOR PROPAGATION.

With the walnuts which pass this test the following information should, so far as possible, be supplied :—

I.—Identification letter and number (suitably the initials of the sender and consecutive numbers) corresponding to those on the label used for despatch of the sample.

II.—The name and address of owner or occupier.

III.—Exact situation of tree.

IV.—Approximate age of tree.

V.—Approximate height.

VI.—Approximate spread.

VII.—Average annual weight of crop, and if variable from year to year.

VIII.—Approximate date of flowering.

IX.—Approximate date when nuts are ripe.

X.—Distance from nearest other walnut tree or trees.

XI.—Local name, if any.

XII.—Local opinion of quality of the nut.

QUALIFICATIONS DESIRED.

(1) One lb. weight should not contain more than fifty nuts, as a maximum, in the fresh condition.

(2) Three-fourths of the sample (*all* of which however should be forwarded) should not pass through a square hole of $1\frac{1}{8}$ inch side.

(3) The nuts should be well sealed and should not show separation of the two halves when moderately pressed along the sutural ridge between the thumb and first finger.

(4) The flavour of the nut must be *rich* (and not merely crisp and palatable) and should not be very astringent when masticated fully.

(5) The nuts should be reasonably uniform in shape and not contain many which are distorted or malformed.

(6) The shell should be sufficiently strong to withstand handling.

(7) To preserve a good colour and avoid development of mould the nuts should be separated from the husk as soon after falling as possible.

A variety which showed any special quality of value, e.g., unusually well-filled nuts, very rich flavour, attractive appearance, heavy crop, etc., but which otherwise did not conform to the desired standard, should also be forwarded for classification, with a note drawing attention to its special merit.

Samples and reports should be sent direct to H. Spence, The Red House, Ainsdale, Southport, Lancs.

NOTES ON SOME UNUSUAL INSECT PESTS ON FRUIT.

By FRED. V. THEOBALD, M.A., F.E.S., Hon. F.R.H.S.

1. The Old Lady Moth (*Mania maura*) (Figs. 1 and 2).

During the winter of 1924 some larvæ were sent me from near Winchester which were eating off the shoots and the buds and barking the shoots of plums, peaches and nectarines. The buds were damaged to a serious extent and in some cases the wood was barked in patches from four or five inches long, but the worst damage was said to be due to the eating right off of the whole shoots. These caterpillars proved to be those of the Old Lady Moth (*Mania maura*) which I have not known as attacking fruit trees to a serious extent since 1889, in which year I find an entry in an old note book that many were attacking standard plums as well as wall fruit at Kingston-on-Thames, where the moth was then very common. Newman in his British Butterflies and Moths (p. 460) records the larvæ as feeding on fruit trees and also as feeding on the foliage of strawberries, but he thought that the latter was uncommon. Its usual food plants given are Docks and Chickweed; Kaltenbach (Die Pflanzenfeinde, 1874) does not mention it on fruit trees, but gives the following host plants: Ivy; (*Hedera helix*); *Lactuca*; *Taraxacum*; *Syringa*; *Urtica*; *Rumex*; *Populus*; *Salix* and *Alnus*.

Fig. 1.
The Old Lady Moth (*Mania maura*) Male and Female and pupa.

The moth (Fig. 1) is a large insect measuring from 2½ to 3 inches in wing expanse; it has a heavy body, the colour is blackish-brown, some a deep purplish-black, with paler lines and some darker markings as seen in the figure; the hind wings are also the same colour with a median narrow pale line and another line near the hind border; both fore and hind wings are markedly

[*Photo by Edenden.*

Fig. 2.
Larva of Old Lady Moth (*Mania maura*)
(slightly enlarged).

scalloped at the edges; beneath the wings have a pale border; the head, thorax and body are blackish-brown and the thorax and body are crested; the antennæ are thread-like. The moth appears in July and continues through August to September, the latest date I have of its occurrence is September 14th, when in 1886 I took several at Kingston-on-Thames. The moths are not often seen flying, except when they occasionally enter rooms of a night attracted by the light. They rest by day in outhouses and sheds, and I have found them to be particularly attracted to dark open summerhouses, where they rest in the darkest corners under the roof. Newman says they are fond of boat-houses for shelter, and he once counted twenty-eight in a boat-house at Godalming. Newman also records an interesting point, "that Mr. Reading says that a marked specimen had returned to the same house after being repeatedly ejected." It is fond of gardens, especially along the course of rivers and streams. It is generally common over England, and I have found it particularly so along the Thames valley.

The female lays her eggs in late summer and autumn, usually choosing fruit trees to deposit them on. The eggs hatch in autumn and the larvæ hibernate, but may as is recorded here feed at times during the winter. The larvæ sent me varied very much in size, some being only half an inch long, others nearly an inch. The colour when mature is dull amber brown, with darker and paler markings, the second to fourth segments have a pale yellowish dorsal stripe and on the dorsum of the segments five to twelve the brown colour forms a deeper coloured lozenge shaped area, there being eight of these, the last cut off, caused by a transversed black bar; on the sides of segments five to eleven are paler and darker markings; the spiracles are reddish, with a black margin and above each a pale oblique bar bordered behind with a black oblique bar and a black mark united to it in front; on the twelfth segment a black bar extends right across. The head is rather small and the body somewhat attenuated in front;

prolegs dingy green and the caudal ones somewhat prominent, ventrally it is dirty green. When mature they are about two inches long (Fig. 2).

During the winter they hide away in the soil by day, but at night come out to feed; in the spring they seem to remain above ground and closely attached to the shoots, their colour making them difficult to see in that position. When on wall fruit they always seem to rest between the stem or shoots and the wall. In spring they feed upon the leaves, but the chief damage is done to the buds, shoots and wood in late autumn and winter. Those kept in the insectary went on feeding until May, when they descended to the soil to pupate. Pupæ were noticed on May 22nd; others pupated up to the end of the month, and a few in June. The first moth hatched out on July 17th. All kinds of fruit trees appear to be attacked, but especially peaches, nectarines and apricots; they also readily feed upon plum and pear and if no other food was given Apple and Cherry, but they did not seem to relish the two latter. It was found that numbers could be killed by prong-hoeing round the stems of the trees during the day and crushing those turned up that were undamaged.

2. THE LARGE EARWIG (*Forficula auricularia*).

At the request of the Ministry of Agriculture I visited a fruit farm near Canterbury in April, 1925, to investigate an unusual form of damage being done to the unopened blossoms and buds of plums. The attacked plums were Monarchs five to six years old, and had been planted the previous November. The plantation of young and old Plums was in a particularly clean state. Few insects of any kind could be found on the trees which were themselves very clean. Large numbers of the buds on the young trees were quite ruined, on some trees up to 90 per cent., and very few of them later showed any blossom. The old established trees were not much affected. The damage was at first thought to be due to the attack of birds, but a casual examination in the field soon showed that they could

[*Photo by Edenden.*

Fig. 3.
Plum Buds damaged and eaten out by Earwigs.

not have been the cause of loss, for the first signs of attack were too small to have been made by any bird, and the final appearance was not like any avian damage that I have seen. The most marked appearance is shown in the photograph (Fig. 3), the whole blossom bud being eaten away, leaving a hollow cup-like cavity. The early stages of damage were quite different, the white cap of the blossoms having evidently been bitten in an irregular manner and leaving small brown lines or spots or patches on the white unopened petals, from this appearance, all stages of damage could be traced up to the total destruction of the buds. I at first thought it might be due to Weevils, especially *Otiorhynchi*, but none could be found under the clods of earth or any debris on the ground at or around the base of the trees or amongst the branches. The bands of sacking around the stakes and trees were next examined and in all that were taken off numbers of the Common Earwig (*Forficula auricularia*) were to be found, in some instances as many as twenty in one piece of sacking. It thus seemed probable that the Earwigs were the cause of the damage. A large number of these insects were taken home in a box with some pieces of undamaged plum. By the time the box was opened, some six hours after, many of the buds were seen to have been attacked in a similar manner to those in the plantation. As this was done under abnormal conditions, some of the Earwigs were sleeved on a plum tree and in a few days examination showed that most of the buds had been damaged. The earwigs ceased to work when the blossom was fully out. Some were carefully watched at night in bell jars and were seen at work on the buds, some of them with their heads buried in the buds, others gnawing the tips, conclusively proving that they were the devastators. It was thought perhaps that the particular strain of *Forficula* in the Canterbury plantation only had developed this habit, but the same species of earwig collected at Wye and slieved in on clean plum branches in considerable numbers produced a similar appearance. Similar damage has been noticed this year at Wye and other places in Kent, but not to anything like such a serious extent. The plantation near Canterbury was so clean that there was nothing for the Earwigs to feed upon except the plums, and this factor probably drove them all to feed upon the buds and finding shelter near under the sack bands they remained hidden in the dark, instead as often happens in the soil. On taking off the bands of sacking many of the Earwigs fell to the ground and at once hurried into the darkness under clods and into any crevice in the soil. To stop this bud destruction the Earwigs can easily be cleared out by untying the bands and holding beneath a circular piece of cardboard made into a funnel and smeared inside with Tanglefoot, most of the insects are thus readily caught.

The damage caused by Earwigs amongst fruit trees is more prevalent than is usually supposed. As this large Earwig rarely flies, unlike *Labia minor*, it can easily be combated by trapping, and for this purpose nothing is better than

coarse sacking, put round the butts of the trees and pieces here and there on the ground. A large proportion of the Earwigs taken were females and they had probably invaded the plantation from the rough belts of woodland surrounding two sides of it.

[*Photo by Edenden.*

Fig. 4.
Young Fruitlets of American Blackberry destroyed by *Thrips*.

3. AN ATTACK OF *Thrips* ON AMERICAN BLACKBERRIES.

Serious damage was done in 1923 and to some extent in 1924 to a plantation of American Blackberries near Chilham, the crop in 1923 being much reduced, at least fifty per cent. of the blossoms and young fruitlets being destroyed. After the petals fall, the fruitlets wither up instead of developing (Fig. 4). In 1924 the damage was about twenty per cent. It was impossible to say what was the cause of the loss from the material sent, as the blossoms were all dried up and

Fig. 5.
Thrips flavus. Schrank.
(Greatly enlarged).

nothing could be found in them. As no fungus was found to develop by Mr. Salmon, the plantation was visited many times and the loss clearly traced to the action of Black Fly or Thrips, of which two species were present in very large numbers. A small proportion only of damage was done by the Raspberry Beetle (*Byturus tomentusus*) certainly not more than two per cent. of the blossoms being attacked by the larvæ of the beetle, and about the same number by the larvæ of the Gall Midge (*Contarinia rubicola* Rbs.). The latter insect produces a very similar appearance to that caused by the Thrips. The Thrips feed in the partially opened and the opened blossoms, and by their constant abrasions cause the whole blossom or the developed fruitlets to shrivel up and to present a very marked appearance shown in the photograph, the dark shrivelled blossoms and fruitlets showing up prominently against the foliage and the sound blossoms. In many instances twenty to thirty Thrips could be found in a single flower when it was opened, feeding below the organs and gnawing them at their junction with the cup. They also damaged the internal parts by laying their eggs in their petioles. The larvæ also attack the plant tissues along with the adults. Both stages were very active when shaken out of the blossoms ; they could not be seen when in the blossoms with ease, except occasionally unless the internal parts were opened out. The adults were found doing most harm in August, but continued to work as long as the blossoms occurred in plenty. The yellow larvæ when mature fell to the ground and became pupæ in the soil, but a few pupæ were formed in the blossoms, an unusual occurrence. This stage lasted from two to four weeks. Two ot the commonest species of Thrips were *Thrips tabaci* (Lind) (Fig. 6), the other yellowish-brown and smaller (*Thrips flavus*, Schrank) (Fig. 5). These were present in about equal numbers in places, but

Fig. 6.
Thrips tabaci. Lind.
(Greatly enlarged).

the smaller paler ones were usually in greater abundance ; numbers of males of the latter were present, smaller and paler in colour than the females. Numbers of *Thrips adusta* (Uzel) also occurred here and there and a few *Limothrips cerealium* (Haliday).

Winter is evidently passed by the two first-named species in the adult stage, for I found great numbers in March hidden in the old galls of *Adelges abietis* on Spruce trees near the plantation and some under the bark on some trees, and a few at the roots of rough grasses. None could be found in the Blackberries in May, but a few occurred in June and these went on increasing, the chief attack coming from the second brood in August and early September. The first two species of Thrips were found in numbers in the wild Blackberry blossoms in the neighbourhood, and I also found them in small numbers in both wild and cultivated Blackberries in other places, but I could not find them in Raspberries, but some in Loganberries. Scattered specimens of the other two species were also found.

Spraying is of no use, as it is impossible to get at the insects hidden in the blossom buds and flowers, and it would be dangerous as many bees would be killed, for great numbers seem to go to the Blackberry flowers.

Poultry run in the plantation seem to do good by evidently eating the Thrips as they escape from the soil. The amount of damage done in 1925 was very small, counts made on several visits showed that not more than five per cent. of the blossoms had been killed. It thus appeared that running poultry had reduced the damage to a negligible amount, particularly as many *Thrips* occurred in Bramble blossoms in 1926 and scarcely any in the cultivated Blackberries in the plantation under observation.

THE PROPAGATION OF FRUIT TREE STOCKS BY STEM CUTTINGS.

I.—OBSERVATIONS ON THE FACTORS GOVERNING THE ROOTING OF HARD-WOOD CUTTINGS.

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Research workers in horticulture have in recent years devoted considerable attention to the nature and properties of the rootstocks which are used for the propagation of fruit trees, and as a result, the importance of using only stocks of known characteristics is now becoming widely recognised.* The circumstances attendant upon the pollination of many fruit varieties, together with their varietal genetic constitution render the use of stocks which have been propagated from seed a somewhat haphazard procedure, since the character of individual seedlings is so variable and cannot be predicted. The natural result of this is that vegetative methods of propagation of rootstocks are generally to be recommended since it is only by this means that uniform plants can be obtained.

It is therefore essential if any particular rootstock is to be of real value, that some method shall be found of multiplying it readily by vegetative propagation.

In commercial practice, plum stocks are frequently multiplied by removing and replanting naturally-rooted suckers from established orchard trees, but this method is, of course, somewhat uncertain, and the numbers obtained are dependent upon the facility with which suckers are normally produced by the rootstock concerned.

Systematic stooling and layering, and propagation from root cuttings are methods which are often resorted to, and it is found necessary to adjust the method and the details of manipulation to the particular variety dealt with (3).

Probably the simplest and cheapest method of multiplying rootstocks would be by means of hardwood cuttings, if the conditions were determined under which these could be relied upon to root and become established. Even in the case of varieties which are readily propagated by stooling or layering, the hardwood cutting method would be more desirable provided a sufficient percentage of cuttings could be induced to produce roots. However, many varieties do not produce satisfactory numbers of shoots from layers or stools, and in some cases, even the shoots which are produced are too weak, or are insufficiently provided with roots for successful nursery work. In such cases the advantage of the

* For results of recent research on this subject, reference may be made to the Annual Reports of Long Ashton Research Station and of East Malling Research Station.

hard wood cutting method, if applicable, is self-evident. Unfortunately when the ordinary technique of propagation by hard wood cuttings is applied to fruit tree rootstocks, the results obtained with the large majority of varieties are quite unsatisfactory, and the numbers of established plants obtained are generally very small. For this reason the hard wood cutting method is very little used in practice.

The advantages offered by the method, together with the necessity of finding some means of reproducing the " shy rooting " varieties provided the inducement to make the observations and experiments here reported.

Experimental.

In the course of the work, two ends have been kept in view—first the elucidation of the principles of root regeneration and the application of these to practice, and second, the discovery by more or less empirical trials, of the conditions best suited to individual varieties.

It is not claimed that the observations recorded in the present paper are all new. The practice of propagation by hard wood cuttings is so ancient that it has naturally become invested with a mass of tradition, and in this research the intention has been to carry out systematic experiments planned largely on the basis of existing traditional practice, in order to obtain specific information on the questions indicated above.

It is not proposed to deal here with the results of trials under a variety of conditions of many different types of rootstock. A description of these experiments would involve the recording of many failures and of some successes which are of interest more especially to the nurseryman. These results will therefore be dealt with only in so far as they throw light on general principles of root formation, and a full description of them is reserved until more comprehensive information is available.

It is with great pleasure that I record my indebtedness to Mr. A. W. Witt, propagator at East Malling Research Station, without whose wholehearted co-operation, the practical details of much of the experimental work could not have been carried out.

At the outset of the work it was desirable to obtain some knowledge of the behaviour of different varieties when subjected to the treatment normally accorded to hard-wood cuttings. From time to time, therefore, batches of cuttings of many varieties have been taken in September or October, cut to a node and planted in a medium loam soil leaving two or three buds above ground level. Each cutting had its base in a small quantity of sand and was " firmed " into the soil in the usual way. These batches were left in position throughout the following growing season and records were made of the percentage which had become established.

The well-known stages in the progress of a cutting from the time it is planted until the end of the following growing season may be outlined here, since frequent reference will later be made to these stages.

The cutting at the time of planting carries two or three leaves, but these soon dry up and fall. Between this period and the dormant season, a callus may develop at the lower cut end of the cutting. This callus in all cases examined, proceeds from the vascular cambium of the stem, and consists of an irregular mass of cells in various stages of lignification, arranged with no very obviously organized relation to each other. The growth from the cambium extends also for a few millimetres inside the base of the cutting which consequently expands. At the same time also, a callus frequently develops at the upper cut end of the cutting exposed to the air, but, this is invariably smaller than the basal callus, and further, if the cutting is planted with its apical end in the ground, the basal callus, now uppermost, is still generally larger than that at the apical end.

Should it happen that no callus is developed during the autumn, the cutting almost invariably dies sooner or later, rotting from the base upwards. In addition to, or as part of this protective and healing function of the callus, its presence greatly retards the absorption of water, as will be shown later.

In some instances of quick rooting varieties, roots may actually develop from a cutting before winter, but more usually this does not occur until the spring, at which season roots and shoots may be developing simultaneously, although of course the actual date depends upon climatic conditions and upon variety.

The establishment of a cutting is very closely bound up with the relation of shoot growth to root growth during this early stage. It frequently happens that cuttings callus well during the autumn, and in spring even begin to produce roots. If, at this stage, a period of warm, dry weather intervenes, the leafbuds expand and leaves are formed. Apparently, in many cases the root system is not large enough under the circumstances to supply water at a rate sufficiently high to compensate for the loss of water by the newly formed leaves, with the result that the cutting wilts and dies. In the absence of the dry spell, such a cutting would frequently become established. Even after the roots have reached a length of two inches many cuttings die as the result of wilting, following a period of high transpiration-rate from the young leaves.

A callused cutting will produce leaves even if no roots are formed, and such a cutting rapidly wilts in a dry atmosphere even if the callused lower end stands in water. If, however, a few millimetres of this end of the stem are removed and the freshly cut end of the leafy cutting be supplied with water, the cutting will remain turgid and alive for some weeks, showing clearly that the presence of the callus is a considerable obstacle to water absorption.

The process of production of roots from a stem cutting, and its subsequent establishment as a complete plant, exemplifies the known tendency of the plant to preserve a more or less definite balance between root production and shoot production. The factors concerned in the attainment and preservation of this balance are but little understood, but emphasis must be laid upon nutrition conditions, as the results indicate.

In the re-establishment of the root-shoot balance in a stem cutting, the primary requirement is, of course, root production, which in practice is found to be a prior essential to any considerable new stem growth, even if external conditions, such as temperature, are favourable to such growth. When a leaf-bud of a cutting first opens, the resulting growth is very short, with a closely packed rosette of very small leaves, having practically no internodes. Such shoot growth indicates deficiency or absence of root activity, although under suitable conditions the cutting may live in this state even for a whole season, becoming properly established a year later. When, however, formation of roots begins, whether in the first or subsequent season, a second type of shoot growth appears from the "rosettes" already present, taking the form of sappy stems with normal internodes, and the appearance of such growth is an indication that the cutting is established.

In the great majority of fruit tree varieties examined, the first roots appear through the callus, and roots from other regions of the cutting are rarely met with in the early stages.

Very wide differences were observed in the frequency with which roots were developed; for example, the Mariana plum roots very readily from hard wood cuttings, nearly every individual developing into a well-established plant in the course of one season. At the other extreme are some of the Mahaleb cherries, no hard-wood cutting of which has yet been induced to root. There is also nearly every gradation between these extremes, and further, any one variety differs from season to season in its behaviour.

Since this is so, it is obvious that both internal and external factors must be taken into consideration in investigating the problem, and in this work both aspects of the problem have been studied.

External Conditions.

The intention of the first experiments on the influence of external conditions on rooting from cuttings, was to obtain first-hand evidence relating to traditional theory concerning aeration conditions. In practice a light sandy soil is advocated as the best medium for rooting ordinary hard-wood cuttings, and emphasis is laid on the necessity for providing efficient aeration and guarding against excessive moisture (1.4.)

Accordingly, batches of cuttings were prepared in the ordinary way and planted in the following media :—

1. Coarse Sand.
2. Medium Loam.
3. Heavy Clay Soil.

The cutting rows were in an open frame in a position not specially sheltered, and were afforded no protection from rain or sun. Several varieties, mainly plums, have been used in the course of these trials and the results have been substantially the same throughout.

At intervals, batches of generally fifty cuttings were removed and examined for callus or root formation. The usual plan was to examine one batch in mid-winter, by which time callus formation should have taken place. A second batch was removed in April or May when the buds were opening, and a third batch was examined later in the year, when it was possible to determine which plants had become definitely established.

It is not of course feasible to measure or weigh the amount of callus produced by each cutting, but an attempt was made to estimate the completeness of callusing by inspection. All cuttings were examined by the same observer and a system of marks was adopted. A cutting which had definitely developed a system of roots and shoots was marked 10, whilst a cutting possessing a root not more than one inch long was marked 8. A cutting with its basal end completely callused over, but without roots, was marked 6, and there were four other degrees of callus recognised, marked respectively 4, 3, 2 and 1. An uncallused or dead cutting was marked 0. The marks for each batch of cuttings were adjusted to a basis of 100 cuttings. The resulting figure was taken as an indication of the batch towards complete regeneration, 1,000 being the maximum figure obtainable.

This system is somewhat arbitrary and was based upon the *a priori* assumption that of ten cuttings possessing roots one inch long or less, eight would become established; of ten cuttings completely callused, six would eventually develop a root and shoot system, and so on. Later, experience has shown that such an assumption is totally unwarranted, since it frequently happens that of ten cuttings completely callused not one eventually produces roots, and it is certain that the marks allotted for callus formation are much too high relative to the marks allotted to rooted plants. In view, however, of the different relation between callus formation and root production, which exists in different varieties, it is manifestly impossible to devise a scheme of marks applicable to all cases.

Therefore, although the eventual root-production of a batch of cuttings usually falls far short of the expectation as estimated from the figures obtained by applying the above method during the stage of callus-formation, nevertheless the method certainly gives comparative figures for the extent of callus

development, and gives approximately the relative rooting capacity of different batches.

The process of callus- and root-development under different soil conditions has now been followed over a period of five seasons, differing considerably from each other in climatic conditions. A single set of results is given in Table I for the Common Mussel plum—a variety which roots only with difficulty from hard wood cuttings.

TABLE I.

Relative Amount of Callus and Roots developed from Hard-Wood Cuttings of Common Mussel Plum under Different Soil Conditions, 1922-23.

Date Examined, 1923.	Progress of Callusing and Rooting in :		
	Sand.	Loam.	Clay Soil.
January 25th	144	148	194
April 20th	204	134	118
August 10th	195	94	53

From this table it is seen that at the first examination, by which date, incidentally, no roots had appeared on any cutting, the amount of callus developed in the cuttings in the heavy soil was greater than that on those on the loam and sand. By April 20th, root-formation had been begun in the sand cuttings, the figure for which had materially increased. The cuttings in clay and loam, however, gave lower figures than at the first examination, indicating that some cuttings which had callused during the autumn had later died ; thus by this time the sand cuttings had overtaken the other batches. At the third examination the difference was still more marked owing to further mortality among the loam and clay series, and as a whole the sand cuttings had fallen a little behind the April figures, since although some had rooted during the summer, several which had previously callused had later died.

The average figures obtained over five seasons 1920-1924 from the variety Common Mussel in sand and clay soil are given in Table II.

TABLE II.

Common Mussel. Relative Callus and Root Development. Average Figures over five seasons.

Examined in	Progress of Callusing and Rooting in :	
	Sand.	Clay Soil.
Midwinter	124	177
Spring	190	174
Summer	263	195

Thus it repeatedly happened that better callus-formation occurs in the heavy than in the light substrate, but the actual formation of roots proceeds more easily in sand.

The Influence of Soil Moisture.

Some obvious conclusions may be drawn from these experiments. It appears that the two processes of callus-formation and root development do not stand to one another in the consequential relation which has been frequently assumed. The foregoing experiments directly contradict the view commonly entertained that good callusing is followed by good rooting. Capacity to root is indeed often estimated from the extent of callus formation. The present results show that on the contrary, the relation of callus production to root development is largely dependent upon external conditions. The former process is definitely favoured by the heavy, water-holding medium, whilst roots are more readily developed in the drier sand. It appears reasonable to conclude from this that high soil moisture favours callusing, and that lower soil moisture, with consequently better aeration, and possibly higher soil temperature, is a condition assisting root-formation. It has been possible to test further the influence of soil moisture upon callusing, both experimentally and by further analysis of the figures quoted above. With regard to aeration and rooting, it is of course recognised that a certain amount of aeration is necessary for root growth but it has not yet been determined whether the difference of aeration between the heavy and the light soils are sufficient to account for the rooting differences. Experiments along these lines are in progress.

It should be noticed here, that whilst the distinction between callus formation and root development is very marked, not only in such experiments as those just described but also in numerous other trials with many varieties, in which callus formation is quite satisfactory but root development is meagre or entirely lacking, yet at the same time some connection between the two processes is perfectly obvious. Different in form and in detail as are root-tissue and callus tissue they are nevertheless both forms of growth, and the general internal and external conditions must therefore in some degree influence both similarly. Further, the protective function of the callus is undoubtedly a factor which influences root-formation especially in varieties slow to root. Some varieties of plants will develop roots and callus simultaneously, whilst others develop a callus at an early stage and roots at a later stage. In varieties of the latter type, should no callus be formed, the cutting rapidly rots, and apparently it is only when bacterial invasion is prevented or restricted by covering the wound, that the cutting is able to survive sufficiently long to produce roots.

Apparently then, callusing and rooting are collateral manifestations of the internal conditions, and there are no indications of their dependence one upon the

other, although it is easy to see how such a view originated. Bailey (l.c. p. 95) says " . . . best results are obtained from callused cuttings but this is probably due to the fact that considerable time is required for the formation of the adventitious buds which give rise to the roots, not to any real connection between the callusing and rooting processes." Van der Lek (6) expresses the opinion (p. 218) that " the formation of the basal callus and the root formation are two processes independent of each other, both depending upon interior factors and exterior circumstances." Also he says (p. 219) "Decidedly there is not such a close connection between the formation of basal callus and the root formation as is usually supposed."

A further study of the results obtained from cuttings in clay and sand give ample evidence of the favourable influence of high soil moisture content upon callus formation. At the time of the experiments, no determinations of the actual soil moisture were made but the rainfall records are available, and an approximate estimate of relative soil moisture may be deduced from these.

Table III gives the total rain for October, November and December of each year of experiment, together with the " callus value " of batches of cuttings in clay and sand as determined at the mid-winter examination.

TABLE III.

Callus Formation of Common Mussel Plum as related to Autumn Rainfall.

Year.	Callus in :		Ratio $\frac{\text{Clay}}{\text{Sand}}$	Autumn Rainfall
	Sand.	Clay.		inches.
1921	30	145	4.8	4.00
1920	60	120	2.0	4.31
1922	216	236	1.1	5.99
1923	178	196	1.1	10.35
1924	208	228	1.1	10.60

The extent of callus formation in sand is closely correlated with the quantity of rainfall and therefore presumably with soil moisture. It may be added that the difference between the rainfall figures for 1920 and 1921 probably does not fully indicate the difference in the soil moisture during these two periods, since the dry summer of 1921 depleted even the subsoil water, and this had a residual effect upon the soil moisture in autumn. This may account for the large difference which was observed in the sand cuttings in these two years, in spite of the small rainfall difference.

The cuttings in clay soil were influenced by rainfall to a much smaller degree than those in sand. This is to be expected in view of the greater capacity of the clay to retain water, so that the conditions would be relatively moist even in a

year of low rainfall, and an increased rainfall would not increase soil moisture in clay to the same extent as in sand.

Thus the ratio of the figures from sand to those from clay shows a gradation corresponding with the rainfall. The cuttings callus better in the heavy than in the light medium except when the rainfall for the period amounts to six inches or more, when even the sand retains sufficient water for good callusing, and the figures are almost equal in both soils.

Further evidence on the question is obtained by a study of the figures for 1922. In this year each batch of cuttings was divided into two portions, one of which was planted and left exposed to the rain. The second half-batch was planted close to the first but was largely protected from rain by an overhead glass shelter with open sides. The two sections were recorded separately and gave the figures shown in Table IV.

TABLE IV.

"Callus Value" of Common Mussel Plum in 1922 under different conditions.

Medium.	"Callus Value."		Ratio.
	Exposed.	Protected.	
Sand	216	72	3.0
Loam	228	68	3.4
Clay	236	152	1.6

In each case the protected cuttings were less well callused than the exposed series, and the influence of moisture difference was much greater in the sand than in the more retentive clay.

A large series of experiments was carried out in 1922, using some eleven varieties of fruit tree stocks each under several different treatments up to a maximum number of nineteen. Each of the batches concerned, amounting to over one hundred, was planted in two portions, one exposed and one protected, in the manner just described for Common Mussel Plum. The ratio of callus production in the protected series to callus production in the exposed (moister) series over the whole range of several thousand cuttings was 100 : 139, providing additional evidence as to the influence of soil water content.

It has not been possible to demonstrate from the experiments on Common Mussel in different media, any such close relation between root-development and spring rainfall, which must influence soil aeration. It is true in general that high spring rainfall is associated with deficient root-formation in clay, but the relation is not so constant as in the case of autumn rainfall and callus formation. This is perhaps not surprising since root-development must be pre-influenced

by conditions other than spring rainfall. For example, a batch of cuttings which has been subjected to autumn conditions favourable to callus formation, since it includes a larger proportion of living cuttings, enters the rooting stage with an advantage over an otherwise similar batch which has not callused well.

In view of the different conditions favourable to the two processes of callus formation and root development, a further experiment was undertaken. Attempts were made to produce callus on cuttings in a heavy soil and to induce root formation by removing the plants in mid-winter to a lighter, drier medium to ensure good aeration during the rooting period. The experiments were carried out over two seasons with two plum varieties involving fifteen batches of fifty cuttings each. The usual procedure was to plant four batches at a time, two in sand and two in clay, and when callus formation was adjudged to have taken place, one batch from clay was removed and replanted in sand, while one batch from sand was removed and replanted, also in sand, to act as a control.

The results were always of the type shown in Table V.

Table V.

Influence of the change of medium upon the " Rooting Value " of Plum Cuttings. Average values for all experiments.

Conditions.	Relative " Rooting Value" (Sand—100)
Sand. Not moved	100
Sand. Replanted in Sand ..	70
Clay. Replanted in Sand ..	55
Clay. Not moved	13

The disturbance involved in the change from sand to sand invariably had a deleterious influence, but in spite of replanting the cuttings callused in clay always rooted very much better if removed to sand than if allowed to remain undisturbed in clay. On the other hand the batches moved from clay to sand never rooted better than those remaining in sand throughout, nor even than those moved from sand into sand. Examination of the cuttings provided an explanation of this. The clay soil used was very adhesive, especially in mid-winter, and in transfering the cuttings from clay to sand it was impossible without laborious individual washing to remove all adhering clay from the base. Consequently on replanting, many cuttings although planted in sand, were provided with a coating of clay at the base which effectively counteracted the influence of the sand. However the experiments provided additional evidence of the effect of the two media upon root formation.

A further method of altering the moisture conditions in the medium has been adopted. Cuttings were planted in sand and heavily watered daily during the period of callus formation, but thereafter no water was added except when there was danger of wilting in late spring or summer. By this means it was hoped to provide the moist conditions which favour callusing, and, later, the drier conditions which appear to encourage root formation. The results, given in Table VI. have shown increased callus formation as the result of increasing soil-moisture.

Similar experiments carried out in loam show that the influence of watering has but little effect upon callus formation in this medium, as might be expected in view of the larger quantity of moisture naturally retained.

TABLE VI.

Comparison of Callus Formation in Plums as influenced by addition of water to the medium.

Variety.	Sand.			Loam.		
	Watered.	Not Watered.	Ratio.	Watered.	Not Watered.	Ratio.
Common Mussel ..	282	212	1.33	—	—	—
,, ,, ..	272	226	1.21	220	214	1.03
Pershore	364	278	1.31	—	—	—
,, ...	380	166	2.29	276	228	1.21
Brompton	346	226	1.54	284	290	0.98

It should be observed that these experiments were all carried out during the years 1924 and 1925 when the autumn rainfall exceeded 10 inches in each case, so that the difference in moisture content effected by watering was comparatively small. In spite of this, watering has increased callus formation in every batch planted in sand. In soil on the other hand, the influence of watering is slight.

It may be significant that in the three cases where comparable experiments are available the callus formation in sand when watered is considerably in excess of that in soil, whether watered or not. The explanation of this may lie in the difference between the bacterial flora in the two cases, or in the intermittent renewal of the interstitial atmosphere which results from the daily watering of sand. In the absence of experimental evidence however, speculation on this question may be profitably deferred.

The experiments are not yet sufficiently complete to show the influence of watering upon subsequent root formation.

Experiments upon the influence of other external conditions, such as

aeration and addition of nutrient salts to the soil, upon root development are in progress.

Internal Conditions.

Whilst external conditions exert a considerable influence upon the behaviour of a cutting, the internal conditions are, of course, of prime importance in determining its capacity to produce roots. It is a first essential that the meristems requisite for root development be present, or be capable of development in the stem, and further, the internal conditions of nutrition must be such as to favour the development of these meristems into roots (7). This latter requirement is obviously an essential, since the cutting cannot obtain a further supply of nutritive substances prior to new root formation, since absorption from the soil is soon restricted by callus production, and no appreciable leaf growth will appear before the roots are formed ; the cutting must therefore exist until that stage, upon its storage-products.

In dealing therefore with the influence of internal conditions upon rooting, the experimental procedure may be directed to alter the number of "root initials" formed in the stem, or alternatively to affect the amount of storage substances in the stem. Naturally the two factors may be closely related and Priestley (l.c., p. 13) suggests that "root initials" may arise as a result of the accumulation of food materials following interruption of the phloem. Some such principle may underlie the practice of ringing shoots which are to be used for cuttings, a process which presumably restricts the dispersal of nutritive substances.

Reed (8) found better callusing when cuttings were etiolated and attributed this to the inhibition of the "hardening" of the pericycle cells which then more readily became meristematic. Reid (9,10) found that rooting from tomato cuttings was favoured by a high ratio of carbohydrates to nitrogen in the stem, and Schrader (11) using the same plant arrived at a similar conclusion.

Starring (12) found consistently better root production from cuttings with a high carbohydrate-nitrogen ratio than from those with a low ratio. Van der Lek (l.c.) has emphasised the importance in the rooting process of the presence on the cutting of leaves and shoots, although he holds that his experiments indicate that the influence of leaves is brought about by the agency of some substance of the nature of a hormone, rather than by accumulation of carbohydrates.

Previously Curtis (2) had tried the influence of variation of sugar content on root formation from cuttings, and found that under some conditions, absorption of sugar by the cutting before planting resulted in improved rooting. Curtis also carried out other experiments in which the object was not to influence the storage materials available for root growth, but to provide substances which

would act as stimulants to growth. Various compounds were used including compounds of manganese, iron and phosphorus and improved rooting frequently resulted, especially from treatment with permanganate.

Following the lines adopted by Curtis, a series of experiments have been carried out since 1920 in an attempt to influence root formation by the introduction prior to planting, of various substances into the cuttings. The cuttings were prepared in the normal manner and were placed with their basal ends in the solution to be tested, and allowed to remain thus for a specified time. After this treatment the cuttings were rinsed in tap water and planted immediately.

The earlier experiments included trials with potassium permanganate (0.05 to 0.0005M.) and cane sugar (0.01 and 0.1M.) and the duration of treatment was from one to three days. In view of the possible antiseptic action of the permanganate, parallel trials were run, using boric acid and also phenol.

During the first two years considerable differences in callusing and rooting capacity were observed as the result of the treatments. Boric acid even at .005M. for one day had a depressing effect on rooting of all varieties, but phenol was variable in its action. The more readily rooting varieties of plums were adversely affected by concentrations as low as .001M. supplied for one day, but the callus formation in some of the apples appeared to be improved by the phenol. There is however considerable variation in the results obtained by applying any one treatment to one variety. Batches which are accorded exactly similar treatment often react quite differently, and the differences from season to season are also large. For example in 1920-21, treatment of apple stock Type II. with .005M. permanganate for one day resulted in an increase of callus formation of over 50 per cent. over that in the untreated batch, whilst in 1921-22 the same treatment of the same variety was followed by a reduction of callus formation to 10 per cent. of the normal. Such variation is extreme, but even treatment with tap water could not be relied upon to give constant results. In the tap water series the root and callus production varied from 84 to 159 per cent. of that in untreated cuttings. With such variations it is evident that very little emphasis can be laid upon the results obtained even with duplicate or triplicate batches consisting of from twenty-five to fifty individuals.

It is difficult, of course, to control conditions affecting hard-wood cuttings planted in the ordinary way, and apparently there was some uncontrolled factor or factors which profoundly influenced the result. Under these circumstances, it is necessary to use very large numbers of individuals in order to obtain a result which can be regarded as trustworthy. Consequently these experiments have been discontinued until further knowledge in other directions has been obtained.

Much more attention has been directed to the influence of carbohydrates upon rooting, and cane sugar has been generally used in the experiments. The method was the same as that described above for the introduction of other substances into the cutting. During 1921 and 1922 the results obtained gave indications that treatment with sugar produced a marked increase in callus- and root-development, although again considerable variation occurred. Table VII. shows the results obtained, expressed as percentages of the values for untreated cuttings.

TABLE VII.

Rooting Capacity as Influenced by Treatment with Cane Sugar Solution. Controls=100.

Variety.	Year.	Tap Water.	Cane Sugar 0.1M.		Cane Sugar 0.29 M. (10%)	
		1 Day.	1 Day.	3 Days.	1 Day.	3 Days.
Apple. Type I. ..	1921	100	200	270	—	—
	1922	105	182	210	146	276
Apple. Type II. ..	1921	89	178	233	—	—
	1922	105	114	177	98	156
Plum. Common	1921	84	89	58	—	—
Mussel	1922	100	87	147	127	280

In 1923, a larger series was planned with the results shown in Table VIII.

TABLE VIII.

Rooting Value as influenced by Treatment with Cane Sugar Solution. 1923. *Averages. Controls*=100.

Material.	Water.			Cane Sugar, 1.0%			Cane Sugar, 10%			Cane Sugar, 40%	
	1 Day.	3 Days.	6 Days.	1 Day.	3 Days.	6 Days.	1 Day.	3 Days.	6 Days.	1 Day.	3 Days.
Apples ..	68	70	—	57	78	73	113	179	70	—	—
Plums ..	82	61	51	79	93	44	99	99	81	22	8
Cherries ..	—	—	—	—	50	—	87	121	—	—	—

Amongst batches which were duplicated or, as was more often the case, triplicated, the deviation from the mean was commonly 20 per cent. The averages in the Table were obtained from four varieties of apple, six of plum and two of cherry.

The most striking feature of the table is probably the fact that if the cuttings stand in tap water only, a reduction in callus formation follows, but this reduction is counteracted by the presence of sugar, at least up to 10 per cent. concentration. Even 10 per cent. sugar however has a depressing influence when the cuttings are treated for six days, whilst one day in 40 per cent. sugar is sufficient to inhibit the rooting process in plums.

The results carry very little promise from a practical point of view, since an increase in the rooting capacity of apples of even 100 per cent. does not bring the use of the hard wood cutting method within the limits of practice. The cuttings used were in all cases typical hard-wood cuttings, that is, "mature cuttings" in the sense used by Curtis, who concluded that immature cuttings were influenced to a much greater extent than mature cuttings, and the results in the present experiments may be due to the condition of the plants. There is an indication of a definite graded effect of the cane sugar which may be useful, since it may be possible to combine the sugar treatment with, for example, some soil treatment. It is evident from the variation of the results from season to season, that an uncontrolled factor was influencing the results, and attempts are being made to discover this source of variability.

Some doubt was felt about the efficacy of the method of the introduction of the sugar. The cuttings were merely standing in the solutions, and the quantity of solution absorbed depended on the transpiration conditions over which no control was exercised. Consequently it is evident that three days' treatment under conditions of low transpiration might introduce less solution than one day's treatment in a dry warm atmosphere. Therefore in the 1923-4 and 1924-5 seasons an investigation was carried out to determine the quantity of solution passing into the cuttings.

Some sixty batches of cuttings were involved, and were variously treated with water and cane sugar at 5, 10 or 15 per cent. concentration. The volume of liquid absorbed was measured, and the concentration of cane sugar in the original and the residual solutions was estimated by the Fehling Method as modified by Lane and Eynon (5). Hydrolysis was effected by 10 per cent. HCl at 68°C. The results showed that when cuttings were placed in a sugar solution there was no *selective* absorption, the concentration in the residual liquid being the same as in the solution originally. There were however, considerable differences in the quantity of liquid passing into the cuttings, and the volume absorbed decreased with increasing concentration. This appears to be due to the fact that when the solution passes up the stem into the leaves, the differences in sugar concentration in the leaves resulting from the differences in the solutions absorbed, produce differences in the transpiration rates which are reflected in the absorption rates.

A typical series of results is given in Table IX.

TABLE IX.

Treatment of Brompton Plum with Cane Sugar Solutions, 1923-4.

Solution.	Period Days.	Original concentration of sugar. %	Final concentration of sugar. %	Volume of liquid absorbed per cutting. c.c.	Wt. of sugar absorbed per cutting. gm.	Rooting value as per cent. of control (untreated).
Water	2	—	—	2.7	—	73
	3	—	—	3.6	—	57
	4	—	—	4.4	—	61
Cane Sugar	2	4.93	4.93	2.0	0.10	82
	3	4.93	4.99	3.4	0.16	53
	4	4.93	4.94	4.4	0.22	54
Cane Sugar	2	9.87	9.80	2.5	0.25	82
	3	9.87	10.06	2.9	0.28	94
	4	9.87	9.92	3.3	0.32	20
Cane Sugar	2	14.80	14.83	2.0	0.30	53
	3	14.80	14.97	2.3	0.33	33
	4	14.80	14.79	2.4	0.36	49

These determinations are of value in showing that under the conditions of the experiment the graded treatment did indeed result in different quantities of cane sugar being absorbed. The influence of the treatment upon rooting capacity was of much the same order as in the previous season.

Concurrently with these a series was run in which potassium nitrate was supplied to the cuttings, instead of, or in addition to cane sugar, and in every case the introduction of nitrate had a distinctly inhibiting effect upon rooting, as shown in Table X.

TABLE X.

Influence of Potassium Nitrate upon rooting of Brompton Plum, 1923-4.

Solution.	Duration of Treatment.	Rooting Value as per cent. of control (untreated).
KNO 2%	1 day	10
	3 days	2
KNO_3 2% + Cane Sugar 10%	1 day	26
	3 days	26

This result is similar to that obtained by Curtis. In using nutrient solutions, all of which contained potassium nitrate, he found an injurious effect on the cuttings.

The investigation of the entry of the sugar solution into the cutting has been carried a stage further. The cutting, during treatment, carries two or three

leaves, which fall shortly after planting, the actual date of fall depending, of course, very much upon atmospheric conditions. If, when sugar is introduced into a cutting, the greater portion passes into the leaves, then as soon as the leaves are shed the sugar is lost to the cutting and can have no further influence on rooting. To investigate this point, some batches of cuttings were treated in the usual way and immediately after treatment the leaves were detached from the stems, and the sugar content of stems and of leaves were determined separately. The sugars were extracted in a Soxhlet with alcohol, the solution cleared with neutral lead acetate, the lead removed and the estimation carried out as before.

Three batches of cuttings were analysed thus,—one batch immediately on removing from the parent plant, a second batch after standing three days in water and a third after three days' treatment with 10 per cent. sugar solution. All analyses were carried out in duplicate. The results are given in Table XI.

TABLE XI.

Distribution of Sugar Absorbed by Cuttings of Brussel Plum. Sugar expressed as Invert Sugar.

Series (20 Cuttings each).	Total Wt. of Sugar gms.			% Wt. of Sugar.		Difference due to Treatment. Total Weight, gms.		
	Stem.	Leaf.	Total.	Stem.	Leaf.	Stem.	Leaf.	Total.
Control ..	0.74	1.88	2.62	1.22	2.08	—	—	—
Water 3 days	0.53	1.07	1.60	0.82	1.11	—0.21	—0.81	—1.02
Cane Sugar 10% 3 days..	1.94	14.64	16.58	3.08	17.60	+1.20	+12.76	+13.96

The total sugar absorbed as determined from the volume and concentration of the original and the residual solutions was 18.3 gms. (invert sugar), of which 15.0 gms. were accounted for by the difference between the second and third series. The remaining 3.3 gms. disappeared, presumably as the result of metabolic changes brought about by the abnormal quantity of sugar present.

The figures show that of 18.3 gms. of sugar passing into the cutting only 1.2 gms. remained in the stem at the end of the treatment. It is probable that after planting such a batch, water would be absorbed from the soil, and there would be a further transference from stem to leaves. On the other hand, a part of the 3.3 gms. of sugar not accounted for in the analyses, may still have been present in the stem in the form of other substances. It is evident, however, that since the absorbed sugar is mainly passed into the leaves, the length of the period after planting during which these remain attached to the cutting, must be a factor in any influence the sugar may have upon the metabolic processes concerned in root production.

It is possible that the divergent results obtained in different seasons may be due in part to this variable factor, and unfortunately the nature of the problem is such that the difficulties of adequate control of this and other variables are almost insuperable. Consequently divergent results must always be expected and large numbers of experiments must be carried out over a series of seasons before conclusions can be drawn with confidence.

SUMMARY.

Trials of several varieties of hard-wood cuttings under different soil conditions showed that the amount of callus formation is not necessarily indicative of the amount of root formation.

Callus formation and root production are two distinct processes bearing no consequential relation to each other, but are collateral manifestations of internal conditions, and the relation between them is very susceptible to external circumstances.

Callus formation is favoured by high water content of the soil and heavy rainfall, whilst root production appears to be favoured by a lower water-content with which is correlated efficient aeration.

Callus formation in a light sandy soil can be greatly increased by constant artificial watering.

With the varieties used, no constant effect, similar to that obtained by Curtis, with *Ligustrum* and tomato, has been observed by treatment with potassium permanganate, boric acid, and phenol ; potassium nitrate decreased root formation.

Cane sugar, when introduced into a cutting has a definite effect upon rooting, and the effect varies with the concentration and with the duration of the treatment. Further, the effect varies from season to season, but the factors causing this variation have not been determined.

When cuttings prior to planting are placed with their bases in solutions of cane sugar, there is no selective absorption, and the concentration of the solutions remains unchanged, although the volume absorbed varies inversely with the concentration. The sugar so absorbed rapidly accumulates in the leaves.

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EXPERIMENTS ON THE CONTROL OF THE APPLE CAPSID BUG.

(*Plesiocoris rugicollis* Fieb.)

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During the last two or three seasons observations have been made on the occurrence of the apple capsid bug throughout the Bristol Province.

These observations have shown that the insect has become a very serious pest in certain districts especially around Ledbury, Herefordshire; in the Cheltenham district of Gloucester; and in the area round Evesham in Worcestershire. In the latter two areas the pest has been responsible for considerable damage to the apple crop and is causing much anxiety among the fruit growers in these areas. No cases of damage from the pest have been found in Wiltshire whilst in Somerset only a few cases have been noted.

In the Herefordshire area and in the Cheltenham and Evesham districts the damage done by the pest has not been restricted to the apple. Considerable damage has been noted on black currants in these areas whilst in the Cheltenham district its ravages have been extended to red currants, gooseberries and strawberries.

In connection with capsid damage to black currants it has been observed that in certain cases the pest has migrated from apple trees during June and July whilst in others the eggs have been laid in wood of the black currant bushes.

The spread of the pest has taken place in spite of considerable spraying against it by growers and in view of the serious situation created by the pest it has been considered desirable to investigate further the methods available for its control.

The present routine method of control throughout the province consists entirely of spring washing with nicotine and soap. The washes used for the purpose usually contain 6-10 ozs. of nicotine per 100 gallons of spray fluid. The opinion is frequently held among the growers who use this method that nicotine spraying as generally practised does not provide an efficient means of controlling the pest though the reason for its failure is not clear.

Previous research on capsid control has been carried out in this country by Fryer (1, 2) and Fryer and Petherbridge (3).

Fryer (1) dealing with the control of capsid bugs states that it is evident that the egg is efficiently protected and that the only method of treating the pest at this stage would be by means of a cover wash such as thick lime wash applied

sufficiently late to leave a coating over the eggs at the time when the insect should emerge. He records the fact that up to the time of writing nicotine and soap sprays have given the best results in controlling the pest and mentions that nicotine sulphate sprays are regarded as satisfactory means of control in America. He refers to the relatively high cost of using sprays containing nicotine or nicotine sulphate for the purpose and stresses the necessity for careful application of the spray.

Later this worker mentions that paraffin emulsion, whale oil soap and lime sulphur were found to be of little service for the purpose in America. In later experiments which he carried out with nicotine and soft soap this spray yielded fairly good results when the trees were thoroughly drenched with the spray.

In summing up these trials, he states that a wash of this latter nature has been found to be only partly successful ; in one case no benefit resulted from its use, possibly owing to the hatching of the bugs taking place over a long period. He considers that in view of such cases as this latter, the need for a more efficient method than nicotine spraying is desirable.

Fryer and Petherbridge (3) record some results obtained in spraying experiments in which nicotine washes were the most efficient of the washes tested.

In considering the problem of capsid control it occurred to the writer that the question of the use of ovicides for this purpose warranted further enquiry. During the last two or three seasons the use of tar distillate washes has become very popular among growers as ovicides against aphis and apple sucker, and critical experiments both in the laboratory and in the field have been carried out to test the efficiencies of various brands of these washes for this purpose. Little attention appears to have been given to the action of these washes on capsid eggs and no account of critical experiments on this subject has appeared to date. Perhaps, it has been assumed, that since the eggs are laid in the bark of the tree the use of such washes was not likely to prove successful. It was felt that this fact did not necessarily rule out the possibility of efficient action of such washes, and as the advantages of the use of such method are so great, it was thought that it should not be passed over without critical trial.

Since the work of the various workers referred to above was carried out a new type of contact wash has appeared on the market. These sprays are heavy oils and from the character of results which the writer has obtained from their use against various aphids, it was thought that they might prove of value as contact washes against capsids.

In accordance with the various considerations outlined above, it was decided to carry out a series of field trials on the control of capsid bug during the season 1925, to test the following as control measures :

A.—Trials with Ovicides.

1. Use of tar distillate washes as winter sprays.

2. Use of late lime-washing as a means of preventing the hatching of the eggs.

B.—Trials with Contact Sprays.

1. Use of spring applications of oil sprays.

2. Use of spring applications of nicotine-soft soap washes.

EXPERIMENTAL.

A.—Trials with Ovicides.

1. *Experiments with tar-distillate washes.*

(a) *Provincial Trials.*—During the course of the Winter 1924-25, five centres were selected for trials with five brands of tar-distillate washes against aphis, apple sucker and caterpillars. During the course of taking records of the results in these experiments it was noted that considerable control had been effected by certain of the brands against capsids. The details of the experimental treatments have been described fully elsewhere (4) and it will only be necessary in this paper to refer to the results obtained.

(b) *Experiment at Cheltenham.*—A block of forty-six apple trees of the variety Newton Wonder, growing in three rows, was utilised in this experiment. Thirty-six of the trees were sprayed, ten being left unsprayed as controls. The control trees were in three groups, one group at either end of the block and the third group across the centre. The tar-distillate wash selected had shown efficient ovicidal action against aphis and apple sucker eggs in previous trials. The spray was applied at 10 per cent. strength, on March 5th. The date was considered late for spraying with a tar-distillate wash since the buds commenced to swell within a few days after its application.

2. *Lime Washing Experiment.*

This experiment was also carried out in the Cheltenham district. Twenty-one trees of the variety Cox's Orange Pippin, constituted the experimental trees. The trees were in one row, seventeen receiving the spray treatment and four, situated at intervals down the row, being left untreated.

The formula of the wash was as follows :—

Quick Lime	..	56 lbs.
Water	..	22 galls.

The sample of fresh lump lime was carefully slaked, the mass being allowed to become as hot as possible during the operation. The slaked lime was allowed to stand for twelve hours before using so as to increase its adhesive power.

Water was added in accordance with the above formula and the liquid was strained through a sieve having approximately sixteen meshes to the inch.

The lime washing was carried out on April 9th, a few days previous to the blossom showing pink.

B.—Trials with Contact Washes.

1. *Experiments with Oil Sprays.*

Two experiments with oil sprays were carried out in the Cheltenham district.

Experiment I.—Trees of the varieties Worcester Pearmain, Cox's Orange Pippin, James Grieve and Allington Pippin were used. From six to ten trees of each variety were sprayed, from two to four trees of each variety being left untreated. The trees had been left unsprayed during the previous winter in order that the effect of the oil spray used alone in the Spring might be observed. The spray was applied at 2 per cent. strength on April 28th. A medium fine spraying nozzle was used and a pressure of from 65-70 lbs. per square inch was maintained in spraying. Care was taken to ensure that the wash penetrated well into the centre of the blossom trusses. The weather during the time of application was dry, hot and sunny, there being little or no wind.

Experiment II.—A block of sixteen trees of the variety Worcester Pearmain was used. Twelve trees were sprayed, four being left as controls. The spray was applied on May 5th on which day the weather was dull, rain falling within a few hours of the spray being applied. The details of application were as described in Experiment I.

2. *Experiment with Nicotine Spraying.*

This experiment was carried out in the same plantation as number I oil spray experiment, and the trees used were of the same varieties as in that experiment. A few trees of each variety were sprayed and controls were left unsprayed for comparison. The formula of the nicotine wash was as follows :

Nicotine (98 per cent.)	8 ozs.
Water	100 galls.

Soap in quantity to 1 per cent. " free " soap.

The application of the spray was carried out under the supervision of the grower two or three days after the application of the oil spray in Experiment I.

Results.

A.—Trials with Ovicides.

1. *Experiments with tar-distillate washes.*

(a) *Provincial Trials.*

A summary of the results obtained at five centres with the five brands of washes used is given in Table I.

Table I.

Tar-Distillate Wash.	Capsid (% hatch).	
	8% strength.	4% strength.
Control (no spray)	100	100
Brand A.	17	56
,, B.	23	43
,, C.	40	73
,, D.	73	83
,, E.	100	100

In judging the results in the field appropriate markings for hatch were assigned on a scale in which a hatch judged as 100 per cent. was represented by the figure 10 ; a hatch of 50 per cent. by the figure 5 and no hatch by 0. The figures obtained for the individual washes was subsequently averaged for the five centres, and these have been calculated on a percentage basis for purposes of presentation in the table.

(b) *Experiments at Cheltenham.*—Observations were made on the effects of the sprays on two occasions during the season, viz., *May 14th* and *July 4th.* No attempt was made to obtain quantitative data from the experiment, though it had been originally proposed to obtain data of crop weights, but this idea was abandoned as the grower decided to thin the fruits on the sprayed trees for show purposes.

On May 14th when the first observations were made, a thorough examination for capsids was carried out on each tree. The weather conditions were excellent for this purpose, being warm and sunny. The bugs were very active and were easily seen. On the control trees one or two capsid bug nymphs were found in about one-half of the trusses, the characteristic damage caused by them being readily discernible.

A very thorough examination was made of the sprayed trees, but only three cases of capsid damage were observed and only two capsid nymphs were found.

On the occasion of the second examination on July 4th, observations were made specially on the amount of damage present on the fruit. That on the

control trees was very badly deformed and a large proportion was entirely unfit for market purposes. The fruit from the sprayed trees was practically free from damage.

2. *Lime-washing Experiment.*

Observations on the effects of this wash were carried out on April 28th. There was no marked difference between the conditions of the sprayed trees and the control trees and it was evident that the spray had not exercised any significant control action.

B.—Trials with Contact Washes.

1. *Experiments with Oil Sprays.*

Experiment I.—The effect of the wash in this experiment was examined on May 14th when the control of capsid bug was judged to be very satisfactory. There was a marked difference in the number of capsid bugs on the control trees as compared with the number on the sprayed trees. Less capsid damage to the leaves was found on the sprayed trees than on the unsprayed section of the experiment.

Observations were also made on the action of the oil spray on the varieties of trees in the experiment and it was found that little damage had occurred. It was observed that on the variety Cox's Orange Pippin the tips of the leaves were slightly scorched. The only other case of injury was that of a single tree of the variety Allington Pippin which was sprayed when the blossom was at the pink stage. The spray caused most of the petals to become brown, and, in many trusses, the flowers did not open.

Experiment II.—When examined on May 14th, the results obtained here were similar to those in Experiment I. The amount of leaf and fruit damage, however, was rather greater when contrasted with the controls, than that observed in Experiment I.

A second examination of the trees was made on October 16th. It was then seen that the control trees were conspicuous because of the inferior shoot growth made during the season. The lengths of the leaders were only from $\frac{1}{4}$-$\frac{1}{3}$ of those of the sprayed trees, whilst the more serious attacks of the capsid bug had resulted in stimulation and outgrowth of the lateral buds, and from two to four shoots were growing out from each leader. The sprayed trees in general produced normal leaders of good growth.

2. *Experiment with Nicotine Spraying.*

As in the experiments with oil sprays, the degree of control obtained by the use of this wash was judged from observations made during the season on the sprayed and control trees on the numbers of bugs present, on damage to

foliage and fruit and on the character of the shoot growth. The spray exercised considerable control but did not entirely prevent damage to the foliage and the fruit, presumably because of the lateness of the spraying.

DISCUSSION.

Examination of the data presented in Table I. will show that considerable ovicidal action was exercised by brands A and B at 8 per cent. strength, the percentage hatch being reduced to 17 per cent. and 23 per cent., respectively. In considering these results it will be of interest to know that Brands A, B, C and D, were efficient ovicides for aphis and apple sucker at 8 per cent. strength, whilst Brands A, B and C were also effective at 4 per cent. strength.

In Experiment b with a tar distillate wash at 10 per cent. strength, the degree of control was very high and as a result of this treatment a crop practically free from capsid damage was obtained when the crop obtained on the control trees was ruined by the pest.

Lime washing treatment proved to be useless in preventing the hatching of the bugs in spite of the fact that the wash was applied only eight days before hatching commenced and should thus have been in excellent condition for exercising inhibitive action.

The degree of control obtained in the first of the experiments with oil sprays was highly satisfactory and it was obvious that a very large proportion of the bugs were killed by the treatment.

In the second experiment the wash was doubtless applied too late to prevent damage to the foliage and fruits from the bugs which hatched first, but that it was effective in killing the bugs and in checking the damage was shown by the large reduction in numbers of the pest on the sprayed trees and by the character of the shoots of those trees later on in the season.

The application of the nicotine spray was made shortly after the oil spray was applied in Experiment I. and previous to that in Experiment II. Here again the spray was applied too late to prevent the early damage to the fruit, but there was no doubt that it exercised efficient control during the remainder of the season.

The results obtained with tar-distillate washes and oil sprays in these experiments appear to the writer to be of great practical importance. It is felt that an important step in the control of Capsid will be achieved if it is found that in future experiments efficient control can be secured by the use of egg killing washes. An additional advantage of using such washes is that leaves produced in the spring after their use are free from curling. This is due to the fact that the eggs of aphis and apple sucker are killed by the wash. There will therefore be greater chance of controlling the surviving capsids with a spring spray.

The substitution of oil sprays for nicotine would also prove of great benefit to the fruit grower owing to the relative cheapness of such sprays and the simplicity of their application. The season's work on the control of this pest suggests that winter washing with a suitable tar-distillate wash at a sufficient strength, followed by a spring application of a suitable oil spray or a nicotine wash will prove to be an efficient method of controlling capsid bug.

Summary.

1.—An account is given of the distribution of the Apple Capsid Bug (*Plesiocoris rugicollis*, Fieb.), and its importance as a pest, within the Bristol Province. The need for further investigations on the control of this pest is emphasised.

2.—Experiments carried out with tar-distillate washes and late lime-washing as ovicidal washes and experiments designed to test the efficiency of oil sprays and nicotine soap washes as contact sprays against the bugs in the spring, are described.

3.—The various experiments show that considerable ovicidal action was exercised by certain tar-distillate washes when used at 8 per cent. and 10 per cent. strengths. Late lime-washing proved to be useless as a method of control. The oil sprays and nicotine-soap washes gave evidence of a satisfactory degree of efficiency as contact washes provided that application is suitably timed. While the tests were not of a character to justify any conclusion as to relative efficiency, the results with the oil sprays taken in conjunction with costs can be accounted as highly promising and justifying exhaustive comparative trials.

4.—The season's work on the control of this pest suggests that winter washing with a suitable tar-distillate wash, followed by a spring application of a suitable oil spray or a nicotine wash will prove an efficient method of controlling Capsid bug.

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TAR-DISTILLATE WASHES.

THEIR COMPARATIVE EFFECTIVENESS, UNDER DIFFERENT CONDITIONS, ON VARIOUS PESTS, AND AT INCREASING CONCENTRATIONS.

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Introduction.

During the autumn of 1923, preliminary experiments with tar-distillate washes were undertaken with the dual object of testing a preparation of known composition alongside proprietary articles of this class, and of evolving a technique by which the toxicity of sprays to insect eggs under field conditions, could be more accurately ascertained.†

The use of tar-distillate or " Carbolineum " sprays for the washing of fruit trees in the dormant period of the year has extended very considerably and as the preparations on the market were all proprietary articles of unknown composition it seemed desirable that tests should be made with a preparation the origin of which was known. By this means it was hoped to obtain a tar-distillate wash made from well-known and easily procurable raw material which would give results as satisfactory as those found in the case of the best of the proprietary preparations.

In this connection it may be pointed out that owing to the variation in chemical composition of the tar-distillates it is impossible to lay down a strictly defined standard even though the raw material may be obtained always from the same source. The tar from which the distillates are obtained varies according to the method of preparation and the coal from which it is obtained and the process of distillation is conducted differently at the various works. The trade however distinguishes certain fractions of the distillation process by specific names such as " light oil," " creosote oil," " anthracene oil," and as these fractions have fairly well defined boiling points it is possible to suggest a formula upon which a wash may be prepared and to subsequently check its composition by chemical analysis.

Such a standard preparation could then be used in field trials and could be prepared if necessary by any maker or even by the grower himself if he were so minded and the method of emulsifying the oil on a small scale were found to present no special difficulties.

† Annual Report, East Malling Research Station, pp. 143-4, 1924.

An examination of a number of proprietary tar-distillate washes led to the conclusion that whilst some of them contained materials other than those derived from coal tar, there was no reason to think that the efficiency of sprays of this class depended upon anything but the tar oils they contained.

Efficient emulsification is, of course essential both to enable the spray to be properly distributed and to minimize the risk of any damage to the tree or its buds.

It will be clear from what has been said above that a proprietary article of undeclared composition may vary considerably from time to time and although it may at one period prove satisfactory there is no guarantee that the same article will be supplied at another time. There is, further, no means of exercising any control of the nature of the material and both from the point of view of the experimenter who may be making trials and the commercial user of the article it seems very desirable that there should be some knowledge of the composition of the article that is being employed.

Owing to the scarcity of eggs in the neighbourhood during the winter of 1923-24, and to the subsequent disappearance of many of them, definite results could not be obtained with the technique employed. However, it was thought that under more favourable conditions, extended trials on these lines would be justified.

During the Winter of 1924-25, a survey of the material available was made, and, as eggs were present in somewhat greater numbers than in 1923, it was decided to continue the trials on a small scale.

The washes used in these trials were two proprietary articles and two tar-distillates prepared for the purpose by Messrs. Newton, Chambers & Co., Ltd., Thorncliffe Works, Sheffield.* The first of the two latter preparations (Standard A) was made from 75 per cent. commercial " light oil " containing 20 per cent. phenols, of specific gravity 1.016 having a range of boiling points as follows :

at 200°C.	..	..	13	per cent.
220°C.	..	..	51	,,
250°C.		..	78	,,
300°C.	..	..	90	,,

Emulsification was by means of rosin and castor oil soap.

The second standard wash (B) was made similarly but with " anthracene or green oil " which had a specific gravity of 1.1 and a range of boiling points as follows :

at 220°C.	..	..	10	per cent.
260°C.	..	..	20	,,
300°C.	..	..	40	,,
380°C.	..	..	60	,,

* It is desired to express our very best thanks to Messrs. Newton, Chambers & Co., for the great interest which they have shown in this question and to their chief chemist for invaluable suggestions and help in connection with the preparation of the above materials.

As the degree of emulsification of the tar-distillate washes may play an important part in their action, special attention was given to the manner in which all the washes behaved when mixed with water and when sprayed on to the trees.

It was found that all four washes mixed well with tap water forming milk-like emulsions with no separation of large globules of tar oil.

When the diluted spray was applied to the trees it was considered that one of the proprietary washes was slightly superior to the two standard washes in the manner in which it spread over the branches and stems whilst the standard washes in turn were superior to the other proprietary wash. No means of judging this point in the field was possible but the fact that all four preparations would be regarded as satisfactory indicates that efficient emulsification apparently presents no special difficulties.

No injury was noticed to the trees or buds but weeds under the trees were severely injured but not permanently killed.

For convenience the various tests carried out may be summarized as follows :

1. Comparative trial of proprietary and standardized tar-distillate washes on the eggs of the Hop-Damson Aphis., (*Phorodon humuli* Schrank) in the field.

2. Complementary test of the same proprietary and standardized tar-distillate washes on the eggs of the Hop-Damson Aphis; (*Phorodon humuli* Schrank) in the laboratory.

3. Test of a standardized tar-distillate wash on the eggs of the Winter Moth (*Cheimatobia brumata* L.), in the field.

4. Test of a standardized tar-distillate wash, at different strengths, on the eggs of the Vapourer Moth (*Orgyia antiqua* L.), in the laboratory.

1. Experiments on the Eggs of the Hop-Damson Aphis in the Field.

Material available.

For this trial there were available twenty six-year-old half-standard Black Bullace plum trees. The trees were planted 15 feet apart, and in one row, with the exception of five in another part of the plot which were set aside to be left unsprayed. Unfortunately, these latter proved to have too few eggs on them to justify their inclusion, so that seven Victoria plum trees, on another part of the ground, had to be substituted as the "controls" in this experiment.

Arrangement of Plot.

Of the fifteen trees in the row, numbers 2, 5, 8, 11, 14, were sprayed with Standard wash A. ; trees 1, 4, 7, 10, 13 with Standard wash B. ; and the remaining five with Proprietary wash C.

Methods of measuring Results of Sprays.

A preliminary survey of the one year shoots was made, and those showing the largest number of eggs were labelled for detailed counts. These marked shoots averaged three per tree.

In January, a pre-spray count of eggs was made on the selected shoots. The numbers of eggs near each bud and in cracks in the internodes were recorded in relation to such "landmarks," so that they might be located again in a post-spray survey. The pre-spray inventory was made in the field with a pocket-lens.

For some weeks before the post-spray examination was made, shoots from the sprayed trees were examined until it was evident that the hatching period was complete. The selected shoots, on which the pre-spray count had been made, were then cut from the trees and the final examination was made between April 4th and 7th. This examination was made in the laboratory with a binocular microscope. The hatched eggs are readily detected by the typical split in the egg, made by the insect in emergence.

Application of Sprays.

The spray was applied on January 23rd, 1925, by means of a hand-manual machine, at a pressure of 75-80 lbs. per square inch. To prevent any possible drifting of spray, trees were protected by a screen made of hessian cloth.

The two standard washes, and the proprietary wash were used at the strength of 7½ gallons of wash to 92½ gallons of water. This was the strength recommended by the manufacturers of the proprietary wash used. The proprietary wash was bought for commercial spraying from the manufacturer's local agent.

The weather conditions were good. There was a slight breeze, but no rain fell till the 26th. There were about four hours sunshine, during the day.

Comparative results of sprays.

The figures obtained as a result of the different treatments are shown in Table I.

TABLE I.

Toxicity of tar-distillate washes to the eggs of the Hop-Damson Aphis in the field.

Treatment.	Number of eggs recorded.	Hatched.	% hatched.	% reduction in hatching.	% viable eggs killed.
Unsprayed	712	392	55	—	—
Standard A. ..	676	245	36	19	35
Standard B. ..	355	114	32	23	42
Proprietary C. ..	407	119	29	26	47

The first three columns are self-explanatory. The normal hatch, on "controls" being 55 per cent., each spray is seen to cause a reduction in the percentage of eggs hatching, as shown in column 4. The percentage of eggs which may be considered as killed by the wash is obtained by calculating the reduction in hatching as a percentage of the normal hatch. For example out of 100 eggs treated with Standard wash A., 36 hatched. But the number which hatched on untreated trees shows that only 55 of this hundred were viable. This indicates that 19 out of 55 viable eggs were killed, that is 35 per cent. The percentages of viable eggs killed, so calculated, are shown in column 5.

General conclusions.

Owing to the scarcity of eggs present, and to the low percentage normally hatching on unsprayed trees, it is not possible to form definite conclusions on the relative efficacy of the different sprays in a single season. It is evident from the high percentage of eggs hatched on the sprayed trees (column 3), that, under the conditions of the experiment, none of the washes used was an efficient control for the pest. This was borne out by later observations which showed both sprayed and control trees slightly infested by the aphis in June.

Finally, there was no evidence of spray damage on any of the trees ; these were examined periodically during and after the blossoming period.

2.—COMPLEMENTARY EXPERIMENTS WITH THE SAME WASHES ON THE EGGS OF THE HOP-DAMSON APHIS, IN THE LABORATORY.

In the autumn of 1924, it was decided to supplement these field experiments, as it was known that these eggs hatched freely on cut shoots kept under indoor conditions, during the winter, in water or water-culture.

A hedge of Myrobolan B plum, heavily infested with eggs, provided excellent material for the trial, and it was realised that the detailed counts of eggs, could be undertaken indoors when rain and poor light made it impossible to record eggs in the field. Finally, it was desired to test whether the normal hatch varied under artificial and natural conditions.

Cut shoots of Myrobolan B, about 12 inches long, which bore sufficient eggs were selected for the experiment. In all 144 shoots were used. The shoots were graded according to size, and representative samples of twelve were placed in each of twelve jam jars, six of which contained water and six a water culture solution. Two jars were used for each of four treatments, the remaining four jars being left as unsprayed "controls." This gave twenty-four shoots for each treatment and forty-eight for "controls."

Method of Recording Eggs.

An exact pre-spray inventory of the eggs on the shoots was made under a binocular microscope. The number of apparently sound and also of shrivelled

eggs, near each bud and on the internodes was recorded. In each case the count began at the apical bud and continued to the tenth bud from the apex. The variety of Prunus used was particularly suitable because the black eggs showed up distinctly on the green shoots. The pre-spray record was made during the third week in December.

Daily observations were made to determine the first date of hatching, which proved to be January 9th. At this date the post-spray survey began, and periodical records of hatching were made on all shoots, with the binoculai microscope. These examinations were made nearly every day from January 9th to February 14th. Only those eggs showing the typical split made by the aphis on emergence were counted as hatched.

Application of Washes.

The three washes used in the field experiment—Standard A, Standard B, Proprietary C—together with another Proprietary tar-distillate (labelled Proprietary D), were used in this laboratory trial. These were used at the strength of 7½ parts of wash to 92½ parts of water. They were not applied with a machine but each shoot was immersed in the spray fluid for about ten seconds. They were allowed to dry before being replaced in the jars. This application was made on December 23rd, 1924.

Comparative Results of Sprays.

The figures obtained are shown in Table 2.

TABLE 2.

Toxicity of tar-distillate washes to the eggs of the Hop-Damson Aphis, in the laboratory.

Treatment.	Apparently sound.	Naturally shrivelled.	Hatched.	% hatched of apparently sound.		% reduction.	% viable eggs killed.
Unsprayed "Controls"	260	104	202	78	75	—	—
	234	81	154	66			
	231	91	187	81			
	159	174	120	75			
Standard A. ..	283	114	99	35	33	42	56
	243	127	73	30			
Standard B. ..	257	121	47	18	17	58	77
	232	177	35	15			
Proprietary C.	229	111	46	20	24	51	68
	254	127	68	27			
Proprietary D.	215	101	44	20	23	52	69
	216	78	53	25			

The first column of figures gives the number of eggs which were apparently normal ; the second column, the number which before spraying were shrivelled or shrunken. These shrivelled eggs were not expected to hatch and are not generally included in the calculations. It occurred however that thirteen of these eggs (less than 1 per cent.) did hatch. These have been included in the figures of column 1.

Referring to the table, it will be seen that the hatch on the " control " shoots was 75 per cent. In this season, therefore, it is an interesting fact that the hatch on controls was 25 per cent higher under artificial conditions than it was in the field. It should be mentioned that the " control " hatch in the field was found to be fairly constantly 55 per cent., on several varieties of plum, and with a large number of eggs, in another series of experiments also. How far such a difference is likely to vary from year to year remains to be shown.

The eggs which hatched on the sprayed shoots, in this laboratory test, varied from 17 per cent. to 33 per cent. The viable eggs killed (calculated as explained in the account of the previous experiment) varied from 56 per cent. to 77 per cent.

It is interesting to compare the results of Tables 1 and 2. Although the percentages of sprayed eggs hatching, indoors and out, are closely similar (17 to 33 per cent. indoors ; 29 to 36 per cent. out) the percentages of viable eggs killed are considerably higher indoors (56 to 77 per cent. indoors ; 35 to 47 per cent. out). This is explained by the fact mentioned above, that the normal hatch was higher indoors. Thus whilst it is possible to make comparative trials of washes in the laboratory, it would appear that care must be taken in thus gauging their actual degree of toxicity in the field.

3.—Experiments with the Eggs of the Winter Moth in the Field.

Since little accurate information as to the effect of tar-distillates on Winter Moth eggs, in this country, was available, it was decided to test one of these washes on a small scale, in the field.

Thirteen bush apple trees of four varieties were available for this trial.

Methods of measuring Results of Sprays.

Owing to the scarcity of eggs and to the fact that they were widely scattered about the branches, it was impossible to select representative shoots for recording, as in the previous experiments. A thorough examination was made of each tree, and the position of each egg observed was marked with a small tag label, tied on the shoot just above or below the egg. This was done during the first week in January.

Periodical examinations were made, and, a week after hatching had ceased on the unsprayed trees, the post-spray examination was made. This continued from May 4th to the 6th. Both examinations were made with a pocket lens. It was

not anticipated that every egg labelled in the first count would be re-located in the final examination. It occurred in the final inventory that the average number of eggs per tree, not traced was almost identical on sprayed and "control" trees. Twenty eggs were not located on five "control" trees, and thirty-one were not found on eight sprayed trees. These were therefore not included in the calculations.

Application of Spray.

The spray used was the tar-distillate hitherto referred to as "Standard A." It was applied at the strength of 7½ gallons of wash to 92½ gallons of water. The trees were sprayed on January 14th, commercially, by a power sprayer.

The results obtained are shown in Table 3.

TABLE 3.

Toxicity of a tar-distillate wash to the eggs of the Winter Moth, in the field.

Treatment.	Eggs labelled.	Hatched.		Reduction.	Viable eggs killed.
Unsprayed "controls"	40 33 21 21 25	35 33 20 20 25	95%	—	—
	140	133			
Standard A. .. 7½ in 92½ ..	21 9 28 14 17 18 40 14	1 1 5 3 6 5 2 1	15%	80%	84%
	161	24			

The first three columns of the table are self-explanatory, and the percentage of viable eggs killed is calculated by the method previously described.

The figures show how the percentage hatch on "controls" affects the percentage of viable eggs killed. Although the hatch on sprayed trees is as high as 15 per cent., the percentage of viable eggs killed is 84. This result seems to warrant a repetition of the trial with the same wash.

Spray injury was not observed on any of the trees.

4. Experiments to Test Various Strengths of Tar-Distillate Washes on the Eggs of the Vapourer Moth, in the Laboratory.

The question of the most efficacious and at the same time economical strength of tar-distillate, seemed of sufficient importance to justify a comparative

experiment in the laboratory, and as Vapourer Moth eggs were obtainable from a neighbouring orchard, it was decided to carry out a preliminary trial.

Systematic collecting in a commercial bush apple plantation, was undertaken, and Vapourer Moth egg batches were carefully removed from the trees. This occupied three days in January 1925, and, as a result, 122 batches were found. Owing to other work more time could not be spent in this search.

The egg batches were placed on filter paper in Petri dishes, ten batches in each. The Petri dishes were placed on wooden boards and surrounded by tree-banding grease to prevent the escape of the caterpillars as they hatched. They were kept in the laboratory.

Application of Sprays.

The spray selected was the tar-distillate "Standard B". The following Table shows the various strengths used and the detailed arrangement of the experiment.

Designation of Treatment.	Strength of Spray.	Number of batches used.
I.	7½ to 92½	30
II.	0 to 100	30
III.	10 to 90	20
IV.	5 to 95	10
V.	3 to 97	10
VI.	15 to 85	5
VII.	20 to 80	17 (some small)

The egg batches were removed from the dishes and were sprayed by means of an atomiser. The spray was applied on February 12th. The following day, the batches were replaced in the Petri dishes, and, from that time until hatching, sprayed and "control" batches were lightly damped with tap water once a week.

Methods of Measuring Results of Sprays.

Daily observations for hatching were made. The first date of hatching was March 17th, and, after this date, with few exceptions, the hatched larvæ were removed twice daily, and their numbers recorded from each treatment. The tree-banding grease effectively prevented migration of the hatched larvæ from one dish of treated batches to another. Thus it was possible to obtain an exact figure for the hatch resulting from each treatment.

During the observations of hatchings, it was found that some of the batches were partially parasitized by a minute Scelionid (*Telenomus dalmanii* Ratz.).* The parasite flies readily so it was not possible to record the number hatching as was done in the case of the Vapourer larvæ. However, in every case in which the parasite was observed while emerging, it was seen to do so through the side

* We are indebted to Dr. James Waterston for the identification of this insect.

or bottom of the egg. The Vapourer Moth larva, on the contrary invariably hatched from the top of the egg.

In a number of cases, after having bitten a hole in the egg, and sometimes partially extruded itself, the larva was unable to free itself completely from the egg shell. The numbers of these have been recorded in the column headed "Dead before total emergence."

The last date of hatching was May 25th. It will be seen therefore that the hatching period extended over more than two months. Some weeks after the last date of hatching each egg was examined with the binocular microscope, the difference in hatching between Vapourer larvæ and Scelionid parasite making it easy to ascertain the number of these latter in the final count. The number of unhatched eggs was also recorded.

The figures obtained in this test are summarized in Table 4.

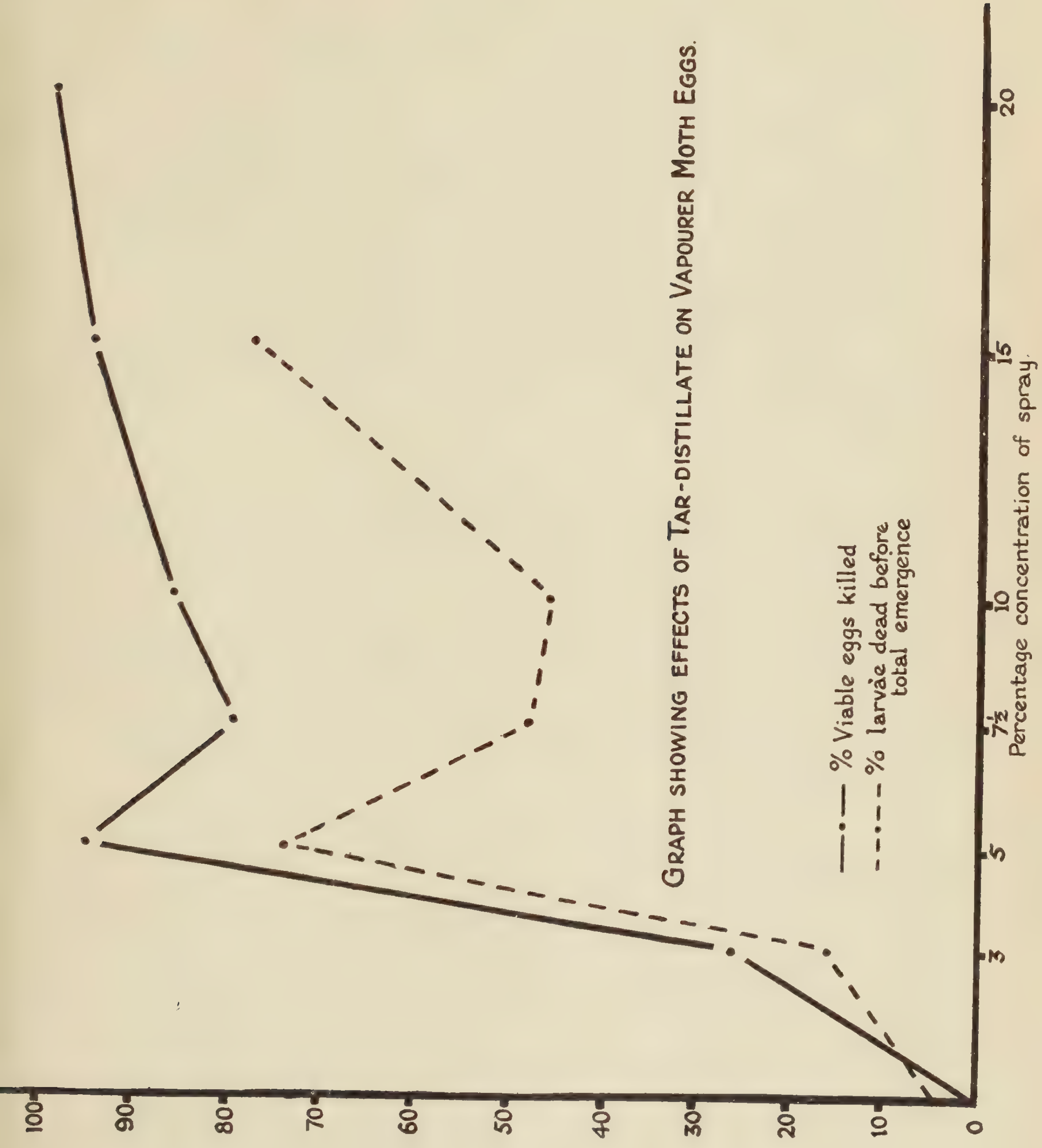
TABLE 4.

Comparative effectiveness of different strengths of a tar-distillate wash against Vapourer Moth eggs, in the laboratory.

Treatment.	Strength.	Total Counted.	Hatched.	Not Hatched.		Eggs Parasitized.	% hatched of total.	% reduction.	% viable eggs killed.
				Not Hatched.	Dead before total emergence.				
II. ..	0	8616	4874	2686	187	869	57	—	—
V. ..	3	2523	1055	1147	217	104	42	15	26
IV...	5	2967	92	2611	264	—	3	54	95
I. ..	7½	8058	982	6183	891	2	12	45	79
III.	10	5309	435	4489	375	10	8	49	86
VI.	15	1062	35	835	125	67	3	54	95
VII.	20	2210	10	2191	8	1	0.5	56.5	99

It will be seen that the percentage hatch in each case is calculated on the total number of eggs used in the treatment. The parasitized eggs are included in the total. It will be realised that the percentage hatch would be higher in the "control" series and some of the other treatments if it had been calculated on the number of eggs not parasitized.

The table shows that, with the exception of treatment IV (5 per cent.) the percentage of viable eggs killed rises with the concentration of the spray, from 26 per cent. in treatment V (3 per cent.) to 99 per cent. in VII (20 per cent.). At present no explanation can be offered for the high kill by Treatment IV, the exception referred to, but it is probably due to some, as yet untraced, source of error. A repetition of this experiment, including the strength 5 per cent.


GRAPH SHOWING EFFECTS OF TAR-DISTILLATE ON VAPOURER MOTH EGGS.
% Viable eggs killed
% larvae dead before total emergence
Percentage concentration of spray.
0
3
5
7½
10
15
20
10
20
30
40
50
60
70
80
90
100

on a larger number of eggs, is being undertaken in 1926 to learn whether these indications are really significant.

The two strengths usually recommended for commercial spraying, namely $7\frac{1}{2}$ per cent. and 10 per cent. are thus seen to have killed respectively 79 and 86 per cent. of the viable eggs.

It is interesting to notice that of the total number of eggs known to contain larvæ (i.e., the sum of the columns "Hatched" and "Dead before total emergence"), the percentage of those dead before total emergence rises with the concentration of the spray, very similarly to the rise in the percentage of viable eggs killed. The foregoing graph shows two curves, 1, the percentage of viable eggs killed, 2, the percentage of larvæ dead before total emergence, both plotted against rise in concentration of the spray.

The similarity of the two curves is apparent. The unexpected feature of a disproportionately high kill at 5 per cent., illustrated in the first curve, is paralleled in the second curve by a similar high percentage of larvæ dead before total emergence.

Summary.

1. In preliminary trials in the field, against Hop-Damson Aphis, tar-distillate washes of known composition, did not prove superior to a proprietary article. None of the washes however proved sufficiently toxic under the conditions described.

2. In similar trials, under laboratory conditions, the washes appeared much more toxic. It was noticeable that a much higher normal hatch was also obtained on shoots indoors.

3. Some information was obtained as to the effectiveness of a tar-distillate wash against Winter Moth eggs in the field. At $7\frac{1}{2}$ per cent. the results were encouraging.

4. Preliminary indications suggest that although higher concentrations of tar-distillate may slightly increase the actual efficiency, probably the optimum strength lies between 5 and 10 per cent.

5. The experiments indicate the possibilities of evolving a fairly accurate technique for measuring the efficiency of egg killing washes in the field.